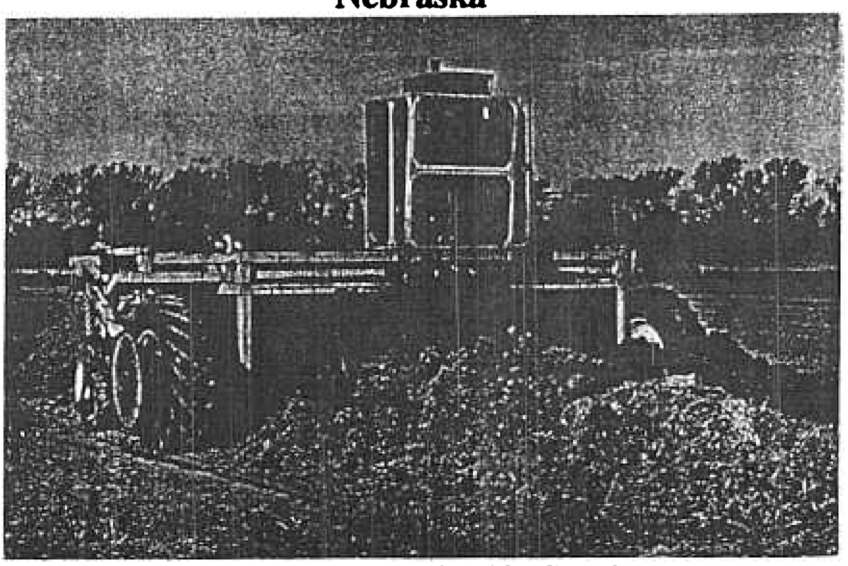
U.S. Fish and Wildlife Service
Region 3
Contaminants Program

A Field Investigation of Sewage Sludge Treatments on Agricultural Production Areas at DeSoto National Wildlife Refuge

in cooperation with the City of Omaha, Nebraska



U.S. Fish and Wildlife Service
4469 48th Avenue, Court
Rock Island, Illinois 61201

February 1993

A FIELD INVESTIGATION OF SEWAGE SLUDGE TREATMENTS ON AGRICULTURAL PRODUCTION AREAS AT DESOTO NATIONAL WILDLIFE REFUGE

U.S. Fish and Wildlife Service
DeSoto National Wildlife Refuge
and
Rock Island Field Office

in cooperation with the
City of Omaha

February 1993

Table of Contents

Table of Contents cont.

List of Tables

List of Figures

List of Appendices

List of Appendices, cont

Abstract

The Fish and Wildlife Service and the City of Omaha participated in a six-year study (1985-1990) to evaluate the environmental impacts of sewage sludge, composted sewage sludge, and commercial fertilizer applications on refuge croplands and the refuge environment.

Baseline chemical concentrations were determined for the study site soils, resident deer (livers), and pheasants (livers). Baseline information also was determined for the soil amendments, including sludge, composted sludge, and commercial fertilizer. Fourteen agricultural plots, comprising a total of 92.8 acres, were then treated for a period of six years with the different soil amendments. Six plots were treated with sludge, compost, and commercial fertilizer soil amendments every other year. Six plots were treated with sludge and compost amendments every year. Two plots received no soil treatments, acting as controls. Residue analyses for metals were then compared with data for the baseline year. Results indicate no major differences for any metal concentrations in any plot among the years tested (baseline (1985, 1987, 1989-90). Differences were found in soil fertility among the test plots. However, these differences were not reflected in the crop yields. Very few conclusions may be drawn from the crop yield data. It is likely that factors external to the controlled parameters were affecting productivity, most likely climatic.

Introduction

DeSoto National Wildlife Refuge has a cooperative farming program in which ten local cooperators annually farm approximately 2,500 refuge acres to provide food, cover, and loafing sites for a variety of wildlife species. The refuge is a migratory resting area for an average peak population of approximately 400,000 snow geese and 50,000 ducks, primarily mallards. Numerous non-game migratory species also use the refuge throughout the year. The abundant resident wildlife populations include ring-necked pheasant, bob-white quail, turkey, fox squirrel, rabbit, and white-tailed deer.

Two crop rotation practices, conventional and biological, were implemented on DeSoto's cropland in 1979. The conventional rotation consists of alternating crops of corn and soybeans. The biological rotation includes a three-year rotation of clover/oats, corn, and soybeans.

Several trial applications of compost and other organic fertilizers have been made on refuge croplands in recent years. However, the benefits from these applications were not evaluated. DeSoto National Wildlife Refuge, in cooperation with the City of Omaha, proposed to compare and evaluate the impacts of various sewage sludge, composted sewage sludge, and commercial fertilizer land applications on refuge wildlife, soils, and crop production to provide more conclusive information on the benefits from organic fertilizer applications.

Many studies have been conducted to evaluate the impacts of sewage sludge applications to agricultural lands. The sewage sludge applied to agricultural fields can be beneficial or harmful to plants, livestock, and wildlife, depending upon its composition and source. Sewage sludge contains elements which might be harmful to crops and wildlife if applied to soils in excessive amounts.

Sewage sludge from the City of Omaha was used because it is relatively contaminant free. Omaha has little heavy industry. Metals of concern were estimated to be of low enough concentration that adverse effects to fish and wildlife would not occur.

Objectives

The objectives of the study were to:

1. Compare, evaluate, and document the impacts of sewage sludge, composted sewage sludge, and commercial fertilizer land applications on soil fertility, wildlife health, and agricultural production.

2. Evaluate the potential to expand sewage sludge and/or compost land applications to other refuge fields.

3. Develop guidelines suitable for use by refuge managers when considering sludge and/or compost land applications.

4. Evaluate the windrow composting method using sewage sludge and plant residues.

5. Compare the ease, suitability, and resulting products of sludge land applications and composting options to aid the City of Omaha, Nebraska, planning future waste management.

6. Compare time, equipment, and staff requirements associated with compost application with similar requirements for commercial fertilizer and sewage sludge applications.

Cooperators

The cooperators in this study are the City of Omaha, DeSoto National Wildlife Refuge, Rock Island Field Office, and Lawrence and Richard Tietz who farmed the test plots from 1985 - 1989, and Norman Buchardt who farmed the test plot in 1990.

Study Area

The study area was located on the DeSoto National Wildlife Refuge and consisted of two fields, totaling 92.8 acres. These fields were divided by a 2.3-acre brome grass strip, which served as the compost pad and sludge storage area.

The two fields were sub-divided into 14 separate test plots. The north field was farmed using the conventional rotation and was 52.5 acres in size. It was divided into eight study plots, ranging from 5.1 acres to 5.4 acres. The south field was farmed using the biological rotation and totaled 50.3 acres. It was divided into six study plots, ranging in size from 7.1 to 8.7 acres.

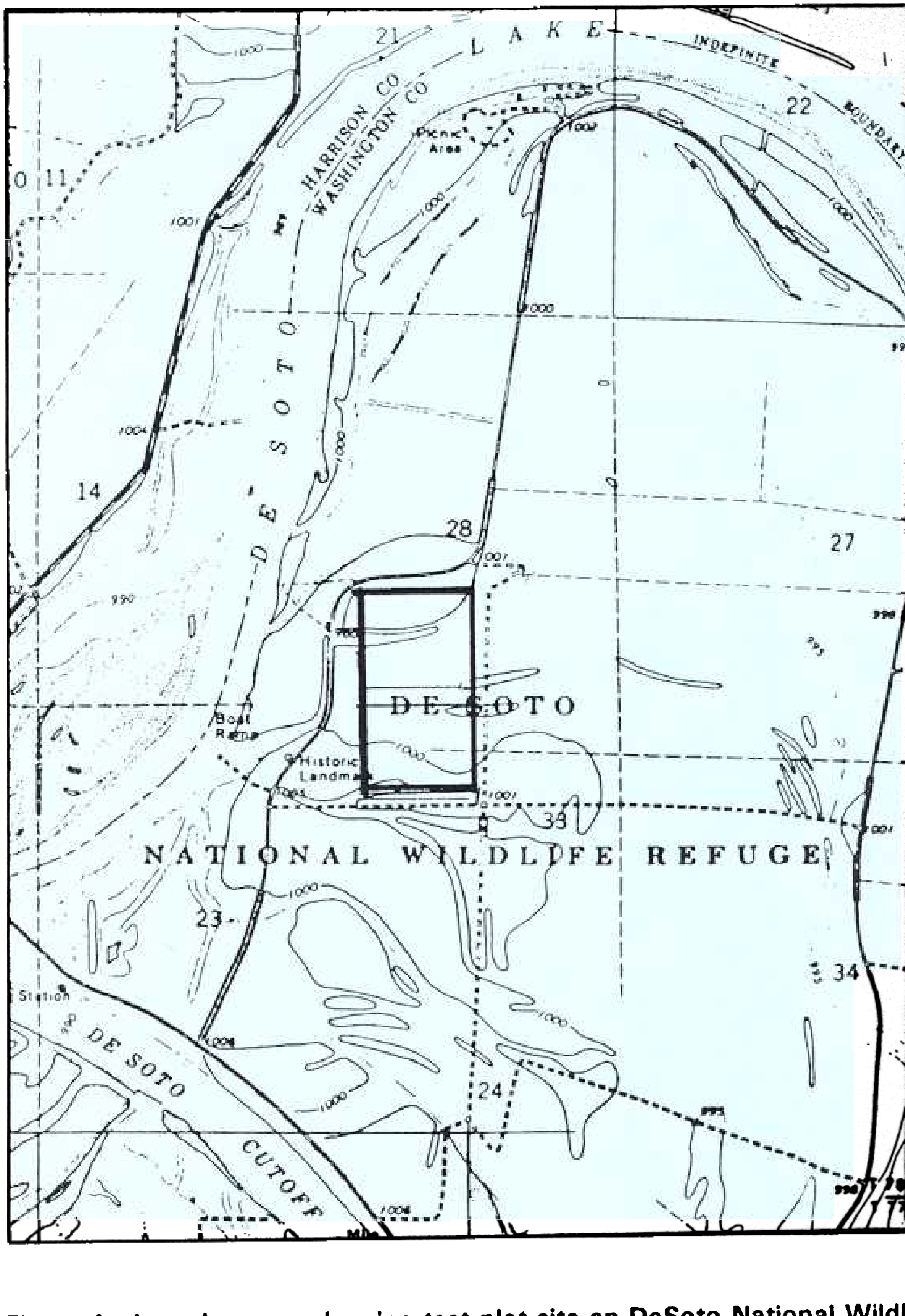


Figure 1. Location map showing test plot site on DeSoto National Wildlife Refuge near Missouri Valley, Iowa.

Methods

The 14 test plots were treated with different soil amendments in spring, at different rates, for the period of 6 years from 1985 to 1990. Half of the plots were under a conventional corn and soybean rotation, starting with corn. The other half of the plots were under a biological rotation for the same years, starting with corn, but included a clover/oats crop. Sludge was applied at approximately 12.2 tons-per-acre dry weight. Compost was mixed the previous fall at approximately 10.9 tons-per-acre and 5.63 tons-per-acre for full-rate and half-rate plots, respectively. Anhydrous ammonia (commercial fertilizer) was applied at approximately 108 pounds-per-acre.

Sludge was applied just before corn planting for conventional and biological rotations, respectively. Plot 2 received sludge every other year for three years (1985, 1987, 1989) during corn planting for the conventional rotation. Plot 7 received sludge every other year for two years (1986, 1988) in the spring before corn planting for the biological rotation. Plots 6 and 9 received sludge every year.

Compost was applied at two different concentrations. Plots 10 and 13 received half-rate compost every year. Plot 3 received half-rate compost every other year during the corn planting of the conventional rotation (1985, 1987, 1989). Plots 4 and 5 received full-rate compost for corn planting only on conventional and biological rotations, respectively. Plots 11 and 12 received full-rate compost each year.

Plot 8 received commercial fertilizer every other year beginning in 1985, and plots 1 and 14 received no treatment, acting as controls. Figure 2 illustrates the plot treatments.

Sludge

Anaerobically digested press-cake sludge of 30 to 35 percent solids from Omaha's sewage treatment plant was transported to the composting pad using 28-cubic yard semi-trailer trucks owned by the City of Omaha's contracted sludge-hauling company. About 1,000 cubic yards of sludge were delivered each year. Part of the sludge was mixed with refuge grasses for compost, and part was applied directly to the fields in spring at a rate of about 12.2 tons per acre dry weight. Sludge residuals were analyzed for all test years by the Missouri River Wastewater Treatment Plant.

Plot 1 5.4 acres No Fertilization Conventional Control Plot	Plot 2 5.4 acres Full Rate Sludge on Corn Only	Plot 3 5.4 acres Half Rate Compost on Corn Only	Plot 4 5.1 acres Full Rate Compost on Corn Only	TREES	Plot 5 7.1 acres Full Rate Compost on Corn Only	Plot 6 8.7 acres Full Rate Sludge Each Year	Plot 7 8.7 acres Full Rate Sludge on Corn Only
	CONVENTIONAL ROTATION 1985 - 1986 - 1987 - 1988 - 1989 - 1990 -	 Corn Soybean Corn Soybean Corn Soybean		COMPOST PAD 1.3 acres		BIOLOGICAL ROTATION 1985 - 1986 - 1987 - 1988 - 1989 - 1990 -	 Corn Soybean Clv/Oat Corn Soybean Clv/oat
Plot 8 5.3 acres Full Rate Commercial Fertilizer on Corn Only	Plot 9 5.3 acres Full Rate Sludge Each Year	Plot 10 5.3 acres Half Rate Compost Each Year	Plot 11 5.3 acres Full Rate Compost Each Year	SLUDGE STORAGE 1.0 acres	Plot 12 8.6 acres Full Rate Compost Each Year	Plot 13 8.6 acres Half Rate Compost Each Year	Plot 14 8.6 acres No Fertilization Biological Control Plot

Figure 2. Study plots for control, dry sludge, wet compost, and commercial fertilizer application, DeSoto National Wildlife Refuge.

Compost

The sludge was mixed with a grass co-composting agent taken from refuge fields. Hay from a mixed stand of cool-season orchard grass, tall fescue, brome, green needlegrass, and wheatgrass was cut and chopped to provide the co-composting agent necessary to produce a suitable carbon-nitrogen ratio for the compost.

The cut grasses were hauled from a refuge field, using a stakebed truck with hoist, and dumped in a linear fashion to promote mixing. Sludge was then dumped along side the hay. The compost contained a ratio of about 1 part grass to 1 part sludge. Mixing was accomplished by several methods including a front-end loader, a maintainer (road grader), a dozer, and a scarab machine. In all cases, the pile was mixed a minimum of three times. Water was hauled and added during several mixings to assist in the decomposition process. However, once mixed, the decomposition process proceeded as planned, with internal windrow temperatures exceeding 150 degrees Fahrenheit for several weeks.

The composting maturation process required about 20 to 40 days. Composting took place during the summer and fall. Mature compost was stored on-site through the winter, and was applied to the test plots in the spring. Both the sludge and compost were applied to the plots using a conventional manure spreader. The compost was applied to the plots in late March/early April. Sludge was applied in mid-April. Crops were planted in early May.

Soil

Soil samples were collected by Service personnel from test plots each spring before application of amendments in 1985, 1987, and 1990. The samples were collected from three locations along a transect down the middle of each plot (Figure 3). The sample locations were equally spaced from each other, and from plot ends and sides. Composite samples consisting of three subsamples were collected: two at the surface and one at a one-foot depth from the middle of each plot. A total of 42 composite soil samples were collected.

Soils were analyzed for ammonia, nitrate, Kjeldahl, and organic nitrogen, organic matter, cation exchange capacity, pH, soil texture, mercury, sulphur lead, cadmium, copper, nickel, zinc, magnesium, manganese,

<u>Plot 1</u> o 1-E o 1-M o 1-W	<u>Plot 2</u> o 2-E o 2-M o 2-W	<u>Plot 3</u> o 3-E o 3-M o 3-W	<u>Plot 4</u> o 4-E o 4-M o 4-W	**TREES** **COMPOST PAD**	<u>Plot 5</u> o 5-E o 5-M o 5-W	<u>Plot 6</u> o 6-E o 6-M o 6-W	<u>Plot 7</u> o 7-E o 7-M o 7-W
<u>Plot 8</u> o 8-E o 8-M o 8-W	<u>Plot 9</u> o 9-E o 9-M o 9-W	<u>Plot 10</u> o 10-E o 10-M o 10-W	<u>Plot 11</u> o 11-E o 11-M o 11-W	**SLUDGE STORAGE**	<u>Plot 12</u> o 12-E o 12-M o 12-W	<u>Plot 13</u> o 13-E o 13-M o 13-W	<u>Plot 14</u> o 14-E o 14-M o 14-W

Figure 3. Soil collection locations on the sewage sludge study site, DeSoto National Wildlife Refuge.

boron, chromium, iron, aluminum, calcium, sodium, potassium, and phosphorous. Metals were analyzed using the Inductively Coupled Plasma Spectroscopy (ICP) method. The cold vapor method was used to analyze mercury.

Mice, primarily Peromyscus maniculatus and P. leucopus, with some Microtus spp., were collected in 1987 and 1989. Three mice were collected from every plot and composited into one sample per plot for metal residue analysis.

Wildlife

Young pheasants were collected from the refuge in 1985, 1987, 1990 using a shotgun and steel shot. Livers from eight pheasants collected in 1985 were analyzed in two composites of three livers and one composite of two livers. Nine pheasant livers collected in 1987 were analyzed in three composites of three livers each. Five pheasant livers collected in 1990 were composited into one sample. The livers were analyzed for 19 metals using the ICP method. The cold vapor method was used to analyze mercury.

White-tailed deer livers were collected in 1985, 1987, and 1990 from hunter-killed deer on the refuge, and analyzed individually for the same parameters and methods as were used for pheasant livers. Ten deer livers were collected and analyzed in 1985 and 1987, while 12 deer liver samples were analyzed in 1990.

Fox squirrels were collected using a shotgun and steel shot in 1985 only. Livers from three squirrels were composited and analyzed for the same parameters and methods as pheasant livers.

Crop Yield and Crop-related Data

Refuge personnel conducted crop yield determinations for each plot. Corn, soybeans, and oats were monitored during their respective growing years for yields. Corn harvest sites were located in the center row, and were equally spaced from each other and from the ends and borders of the plots. All the ears on three separate 14.5 foot transects down the middle of each plot were harvested and used to project corn yield per acre.

Results

Soil - Metals

In general, heavy metal concentrations of cadmium, chromium, copper, lead, and zinc increased detectably from the base year of 1984 to the final application year of 1990. However, the no-fertilization plots (1 and 14) also increased at about the same rate as the treated plots for copper and zinc. Chromium increased two to three times greater in the treated plots than in the non-treated plots. Cadmium increase was due mainly to one site, plot 2, which had one sample concentration of 28.5 ppm in 1990. Lead increased two-fold in 1987 (from 11 ppm to 23.4 ppm) in the yearly sludge treatment plots. This was a higher increase than for any other treatment plots or control. Concentrations of lead in all treatment plots in 1990 were similar at about 5 ppm higher than the baseline year, while the control plot decreased by 2.4 ppm. Nickel changed little between plots or between test years. Comparisons of selected metals between treatments and years are presented in Tables 1, 2, and 3. Complete soil metal analyses are included as Tables A-1, B-1, and C-1 in Appendices A, B, and C, respectively.

Background concentrations of cadmium determined from 1985 data were at or slightly above detection limits. The 1987 results were similar to those of 1985 for all treatments. However, in 1990, cadmium concentrations were slightly higher in some treatment plots than others. Most sites averaged between 0.26 - 0.33 ppm cadmium. Plots 2 (sludge applied every other year), 6, 9 (sludge applied every year), and 12 (compost applied every year) had slightly elevated values (about 0.1 ppm higher) than other treatment plots. Plot 2 had one value of 28.5 ppm, and one at 0.89 ppm. Chromium also was slightly elevated in plots 2, 6, 9, and 12 in 1990.

Heavy metal concentrations determined in the test plots were all well below levels of concern, except for cadmium. The New Jersey Department of Environmental Protection (1987) cites 3 ppm as the criterion for cadmium in soil while the national average of cadmium in soil is 5 ppm (Davies 1986). Only one sample point of 28.5 ppm in plot 2 (sludge application all years) in 1990 exceeded those concentrations.

Wildlife - Metals

Deer livers and pheasant livers taken in 1985, 1987, and 1990 were compared for potential uptake of metals. Analytical results indicate that slight increases were detected between 1985 and 1990 in deer livers for chromium and copper (Table 4). In 1990, three deer liver samples had

Table 1 Mean values for selected metals in test plots from DeSoto National Wildlife Refuge for 1985

	SOILS - 1985 (ppm dry weight)			
	Plots 1,14	Plots 6,9	Plots 2,7	Plots 11,12
Cadmium	<0.5	<0.5	<0.5	<.4
Chromium	6.7	14.0	8.9	9.5
Copper	8.5	13.4	9.8	10.5
Nickel	15.2	19.7	16.6	16.6
Lead	10.3	11	10.7	9.4
Zinc	39.5	53.2	42.8	43.7

Table 2. Mean values for selected metals in test plots from DeSoto National Wildlife Refuge for 1987.

	SOILS - 1987 (ppm dry weight)			
	No Fertil-ization (mean) Plots 1,14	Full Sludge applied '85-'90 (mean) Plots 6,9	Full Sludge Applied '85,'87'89 (mean) Plots 2,7	Full Compost Applied '85-'90 (mean) Plots 11,12
Cadmium	<0.5	0.6	<0.5	<0.5
Chromium	7.4	19.6	14.05	24.6
Copper	8.3	14.1	11.13	22.4
Nickel	13.7	16.2	15.3	12.4
Lead	7.9	23.4	10.0	8.6
Zinc	43.4	59.0	51.45	39.5

Table 3. Mean values for selected metals in test plots from DeSoto National Wildlife Refuge for 1990.

	SOILS - 1990 (ppm dry weight)			
	No Fertil-ization (mean) Plots 1,14	Full Sludge applied '85-'90 (mean) Plots 6,9	Full Sludge Applied '85,'87'89 (mean) Plots 2,7	Full Compost Applied '85-'90 (mean) Plots 11,12
Cadmium	0.3	0.52	5.1	0.43
Chromium	14.9	43.4	29.4	31.7
Copper	13.0	17.1	12.6	14.0
Nickel	15.0	18.7	14.0	16.5
Lead	9.2	16.7	15.5	14.2
Zinc	47.3	64.5	52.8	54.7

Table 4. Mean values for selected metals in deer livers from DeSoto National Wildlife Refuge for 1985, 1987, 1990.

	DEER LIVERS (ppm dry weight)		
	1985 (mean)	1987 (mean)	1990 (mean)
Cadmium	0.20	0.67	0.3
Chromium	1.91	0.80	4.2
Copper	87.7	96.5	104.9
Nickel	<2	<2	5
Lead	<0.3	<5	5.3
Zinc	123	146.3	85.0

Table 5. Mean values for selected metals in composite samples of pheasant livers from DeSoto National Wildlife Refuge for 1985, 1987, 1990.

	PHEASANT LIVERS (ppm dry weight)		
	1985 (mean of 3 composited samples)	1987 (mean of 2 composited samples)	1990 (1 composited sample)
Cadmium	0.3	0.777	<.1
Chromium	2.5	0.69	0.95
Copper	24.6	19.7	13.4
Nickel	<0.5	<2	<.5
Lead	<1.5	<5	<1.5
Zinc	86.8	108	65.4

nickel and lead above the detection limit.

Concentrations of zinc in pheasant livers was highest in 1987 (Table 5). Baseline year (1985) concentrations for chromium and copper exceed those for test years. Concentrations of cadmium, nickel, and lead remained near or below the detection limits for all test years in pheasant livers.

Whole body mice residue analyses compared mice collected from control and treatment plots (Tables 6, 7). For all plots, there was a detectable decrease in concentrations of copper and zinc between 1987 and 1990 samples. All 1990 samples analyzed for copper and zinc were lower than the control plot sampled in 1987. Cadmium, nickel, and lead remained at or near the detection limits at all plots for both years. Chromium in treatment plots for both years varied by about 0.1 ppm from the control.

Sludge

Sludge was analyzed by the City of Omaha for the years 1985 through 1990, and is reported in Appendix E, Table E-1. The sludge averaged 3.6% total nitrogen, 0.8% ammonium nitrogen, and 0.007% nitrate nitrogen. Phosphorus averaged 1.6% and potassium 0.15%. For heavy metals, zinc averaged 660 ppm, lead averaged 204 ppm, copper 180 ppm, nickel 32 ppm, and cadmium averaged 8.9 ppm for the six-year period. These heavy metal concentrations are below State of Iowa standards for "good" usable sludge and are below the new standard set forth by the U.S. Environmental Protection Agency (Fed Reg. Vol. 58, No. 32, Feb. 19, 1993). Table 8 compares these values. The project site is in the State of Nebraska which has no State standards for land applied sludge.

Nutrient Content - Soils

Concentration of total nitrogen in the soils was generally higher in 1987 than in 1985. However, this trend did not continue in 1990. Overall, there are no strong trends in the total nitrogen determined among the plots for all years. Sludge plots 2 and 9 generally increased in total Kjeldahl nitrogen (TKN) from 1985 to 1990. Control plot 1 also increased in TKN over this time period. Commercial fertilizer plot 8 decreased slightly over the same period. A summary table of TKN values from selected plots are presented in Figure 4. All soil analyses values are reported in Tables A-4, B-4, and C-4, Appendices A, B, and C, respectively.

Table 6. Mean values for selected metals in whole mice composites from DeSoto National Wildlife Refuge for 1987.

	WHOLE BODY MICE COMPOSITES - 1987 (ppm dry weight)			
	No Fertil- ization (mean) Plots 1,14	Full Sludge applied '85-'90 (mean) Plots 6,9	Full Sludge Applied '85,'87'89 (mean) Plots 2,7	Full Compost Applied '85-'90 (mean) Plots 11,12
Cadmium	<0.5	<0.5	<0.4	<.5
Chromium	1.8	1.5	1.7	1.4
Copper	11.9	10.9	12.0	10.7
Nickel	<2	<2	<2	<2
Lead	5.2	<5	<5	<5
Zinc	109	106	114	106.2

Table 7 Mean values for selected metals in whole mice composites from DeSoto National Wildlife Refuge for 1990.

	WHOLE MICE COMPOSITES - 1990 (ppm dry weight)			
	No Fertil- ization (mean) Plots 1,14	Full Sludge applied '85-'90 (mean) Plots 6,9	Full Sludge Applied '85,'87'89 (mean) Plots 2,7	Full Compost Applied '85-'90 (mean) Plots 11,12
Cadmium	<0.1	<0.1	<0.1	<0.1
Chromium	1.6	1.5	1.7	1.4
Copper	8.2	7.9	5.1	7.8
Nickel	<.5	<.5	0.6	0.56
Lead	3.0	<1.5	<1.5	1.7
Zinc	84.6	95.5	71.8	75.0

Table 8. Metal concentrations in the sewage sludge of the City of Omaha compared to standards for the State of Iowa and U.S Environmental Protection Agency.

	SEWAGE SLUDGE - METAL CONCENTRATIONS (ppm dry weight)		
	Project Sludge City of Omaha (mean))	State of Iowa[1] "Good" Sludge	U.S.EPA[2] 1993 Ceiling Concentrations
Cadmium	8.9	15	39
Chromium	2.5	0.69	0.95
Copper	180	1000	1500
Nickel	32	200	420
Lead	204	1000	300
Zinc	660	2000	2800

1 Iowa Department of Natural Resources (IAC 567-121)

2. Table 3, Standards for the Use or Disposal of Sewage Sludge, Part 503, Subpart B-Land Application (Fed. Reg. Vol. 58, No. 32, Fri, Feb. 19, 1993, p. 9392.)

Plot 1	Plot 2	Plot 3	Plot 4
5.4 acres No Fertilization % Bu/Ac Year TKN Yield '85 .07 140 '87 .1 173 '89 .09 110	5.4 acres Full Rate Sludge on Corn Only % Bu/Ac TKN Yield .09 172 .08 178 .10 95	5.4 acres Half Rate Compost on Corn Only % Bu/Ac TKN Yield .08 146 .08 150 .08 145	5.1 acres Full Rate Compost on Corn Only % Bu/Ac TKN Yield .05 83 .13 115 .05 138
Plot 8	**Plot 9**	**Plot 10**	**Plot 11**
5.3 acres Full Rate Commercial Fertilizer on Corn Only. % Bu/Ac Year TKN Yield '85 .08 178 '87 .07 127 '89 .07 110	5.3 acres Full Rate Sludge Each Year % Bu/Ac TKN Yield .06 161 .07 182 .12 75	5.3 acres Half Rate Compost Each Year % Bu/Ac TKN Yield .12 139 .15 142 .10 145	5.3 acres Full Rate Compost Each Year % Bu/Ac TKN Yield .09 123 .14 115 .08 78

Figure 4. Total Kjeldahl nitrogen and yield from selected plots on the sewage sludge study area, DeSoto National Wildlife Refuge for 1985, 1987, and 1990.

Phosphorus and potassium levels in the soil remained high to very high for generally all test plots, including the controls, throughout the test years.

Yields

Corn

Corn harvested from control plot 1 were generally reduced in yield from 1985 to 1989 except for a small increase in 1987. In 1985, plot 1 yielded 140 bushels-per-acre of shelled corn. In 1987, it yielded 173 bushels-per-acre, while in 1989, plot 1 yielded only 110 bushels per acre of shelled corn. In 1990, three plots had lower yields than the control plot. These were plots 2, 9, and 11 yielding 95, 75, and 78 bushels of shelled corn, respectively. Plots 3, 4, and 10 were the highest yielding sites in 1989, with 145, 138, and 145 bushels-per-acre of shelled corn, respectively. These three plots all had applications of compost. However, only plots 4 and 10 had an increase in yield over baseline year 1985.

Soybeans

Soybeans decreased in production in all years after the initial planting year 1986 at all plots. The yield for all plots sampled in 1990 varied little, with a maximum difference occurring between plots 2 and 11 of 13.6 bushels-per-acre.

Discussion

Metals

Metals in sewage sludge may be toxic to plants if present at high levels. Some trace elements essential to plants are included in this group. The elements most likely to cause damage are arsenic, zinc, copper, nickel, cadmium, chromium, mercury, lead, boron, molybdenum, cobalt, and selenium. Most metals accumulate in plant roots or leaves. Few toxic metals, such as mercury and molybdenum, bioaccumulate to high levels in seeds. Plant roots have the capability of controlling the uptake of elements they need and excluding the ones for which they have an adequate supply. This protects them from high soil concentrations of some elements.

If crops, particularly corn, have elevated concentrations of metals, wildlife may not be exposed, because wildlife may feed on other plants not exposed to elevated metal concentrations. Also, the duration of corn availability is limited such that it may only be available to wildlife one to three months per year. Wildlife analyzed for this study did not indicate elevated body burdens of metals above the controls.

In general, soils amended with sewage sludge containing relatively low concentrations of metals such as that from the City of Omaha, would require 15 to 20 years of applications before metals would accumulate to levels which may affect plants or wildlife (Sommers, Nelson, and Spies 1980).

Cadmium

Cadmium, a nonessential element, can be a serious hazard to animals if dietary levels are high. Cadmium highly concentrated in soils is toxic to plants. Normally, cadmium levels in most sludges are not high enough to cause plant injury, but some sludges contain appreciable quantities. Plant tissues may contain high concentrations without showing toxic symptoms. Cadmium levels in grain are usually much lower than in other plant tissues.

One of the greatest threats to wildlife of applying sludge to agricultural lands is the cadmium content of the sludge. Low levels of cadmium in the soil may be hazardous to earthworm-eating wildlife. Beyer (1990) reported that cadmium was biomagnified to 100 ppm in earthworms collected from soils containing only 2 ppm cadmium. (Collection of earthworms was attempted for this study, but was unsuccessful due to a long history of chemical use, including anhydrous ammonia, which is detrimental to earthworm populations.) Beyer also reported high levels (25 ppm) of cadmium in carrion-feeding insects

Cadmium concentrations for all tissues analyzed hovered around the detection limit, except deer and pheasant livers in 1987, which averaged about 0.7 ppm. Walsh et. al. (1977) consider cadmium whole-body levels of 0.5 ppm to be harmful to fish and predators (our study analyzed livers which should be more concentrated than whole-body analysis).

Cadmium was highest in the sludge analyzed in 1987. The reported concentration of cadmium in sludge for that year was 19.4 ppm (Appendix E, Table E-1). This slightly exceeds the sludge standards set forth by the State of Iowa, for example, which is 15 ppm (the study site is located in Nebraska which has no sludge standards). However, it does not exceed the standards set forth by the U.S. Environmental Protection Agency in their 1993 regulations on disposal of sewage sludge (40 CFR Part 257 et al., Fed. Reg. Feb 19, 1993). Table 1 of those regulations set 39 ppm (dry weight basis) as the maximum average monthly concentration for cadmium.

Cadmium was not found elevated above background concentrations in soil samples, except one. One sample from plot 2 (sludge applied all years) in 1990 was detected at 28.5 ppm. This sample may be an aberration, or it might be a "hot spot." Additional sampling should be performed to confirm or deny its existence.

Chromium

Chromium increased two to three times in the treated plots, compared to the non-treated plots, for all years. Chromium is considered one of the 14 most noxious heavy metals (Jenkins 1981). Chromium also is listed among the 25 hazardous substances thought to pose the most significant potential threat to human health at priority superfund sites (U.S. Depart. of Health and Human Serv. and U.S. EPA 1987). Mean chromium concentrations in this study increased between years and increased in treatment plots to a higher degree than non-treatment plots. Concentrations still remained below levels of concern (U.S. Environmental Protection Agency (1983) has proposed a criteria of 100 ppm chromium in soils).

The greatest chromium risk to plants is posed in acidic sandy soil with low organic content (National Library of Medicine, 1988). In plants, chromium interferes with uptake translocation, and accumulation by plant tops of calcium, potassium, magnesium, phosphorus, boron, and copper. It also aggravates iron deficiency chlorosis by interfering with iron metabolism (National Library of Medicine 1988).

Little is known about the effects of elevated tissue levels of chromium on fish and wildlife. Apparently, the only chromium concentration that has been proposed as a protective standard for animal tissues is 0.20 mg/kg (Eisler 1986). U.S. Fish and Wildlife Service studies in the Southwest consider chromium levels above 0.8 mg/kg in fish and wildlife tissues to be elevated (O'Brien 1987; Kepner 1986; Irwin 1988). Deer tissues sampled in 1984 and 1987 exceeded the 0.20 mg/kg standard for chromium (1990 detection limits were 0.9 mg/kg). In 1990, three deer liver samples had concentrations of 14, 15, and 17 ppm chromium.

Copper

Copper, although an essential element, can be toxic to plants at high concentrations. Plants exposed to excessive levels of copper will usually show toxic symptoms before they can accumulate enough copper to be toxic to most animals. However, some animals are extremely sensitive to low dietary copper levels. Copper is not biomagnified by earthworms, but carrion feeding insects do accumulate copper.

Copper in soils increased in treatment years at a rate comparable to the control. All values were below levels of concern. Jenkins (1981) reports typical soil concentrations to be 20 ppm dry weight while the national average is 30 ppm (Davies 1986).

Mean copper concentrations in deer livers were about 10 percent higher in 1987 and 16 percent higher in 1990 (96.5 ppm and 104.9 ppm, respectively) than in the baseline year 1984 (87.7 ppm). Mean copper concentrations in pheasant livers were higher in the baseline year 1984 (24.6 ppm) than in any treatment year.

Molybdenum

Molybdenum is not particularly toxic to plants, even when present at high levels. It may accumulate in plants at concentrations sufficient to cause molybdenosis in ruminant animals without prior indications of toxicity to the plant. This element is usually present at low levels in sludge. However, if present at high levels, it can cause problems for wildlife.

Molybdenum was found in concentrations at or near detection limits for all soils and organisms sampled.

Nickel

Nickel is not essential to plant growth. Although nickel may occur in substantial quantities in sludge, nickel is only toxic to plants growing on acid soils. If the soil pH is maintained at 6.5 or above, nickel should not cause plant toxicity. Nickel is toxic to plants at concentrations that are relatively safe for animals. Therefore, nickel contaminated plants are probably not a food chain problem.

No significant difference was found among concentrations of nickel in soils or organisms. Most values were at or near detection levels, except three deer livers in 1990 determined to be above detection limits.

Zinc

Zinc is an essential element for both plants and animals and is often present in sludge and soils at relatively high concentrations. Additions of sludge to soil may cause substantial increases in the zinc content of plants, but plant toxicity seldom occurs. Many animal diets are deficient in zinc, so a wide margin of safety usually exists between normal dietary intakes and those which produce zinc toxicity in birds and animals. Absorption of dietary zinc is regulated in part by proteins (Schiffer 1989). Zinc levels in earthworms may biomagnify over four times greater than zinc levels in soils (Beyer 1990). Carrion-feeding insects may have high body burdens of zinc. Zinc concentrations in control and test soils increased in 1990 by about 10 ppm overall from the baseline year.

The highest concentration of zinc in tissues reported for this study was 271 ppm for a deer liver analyzed in 1987. Average normal levels in cattle liver are 135 ppm. In animals suffering from zinc toxicity, corresponding values for liver are 2000 ppm (Clarke, Harvey, and Humphreys 1981).

Lead

All measured effects of lead on living organisms are adverse, including those affecting survival, growth, learning, reproduction, development, behavior, and metabolism (Eisler, 1988). It is a nonessential element that exhibits a low degree of potential toxicity to plants, because soil constituents react with it to reduce its solubility (and availability to plants) at pH levels above 5.5. Lead can be toxic to plants in low pH soils that are low in phosphate. Usually, lead in sludge is non-toxic to plants, because the phosphate makes the lead unavailable. Lead tends to accumulate in plant parts growing closest to the ground. Small rodents and other animals important in the food chain that feed on roots may accumulate high body burdens of lead. Lead does not biomagnify in earthworms.

Lead in the soils was detected at low background concentrations for the baseline year, and for the following test years. Most soil values were below 21 ppm, and only three were at that concentration. However, typical soil concentrations are considered to be 10 ppm dry weight (Jenkins 1981; Davies 1986)

Lead was found at or near detection limits for all organisms tested for all study years, except in 1990, where three deer livers had lead concentrations slightly above the detection limits (9 - 10 ppm, <4 ppm detection limit).

Other Metals

In addition to the metals previously listed, sewage sludge normally contains manganese, iron, aluminum, and mercury. The toxicity of these metals to wildlife or crops are considered to be minimal because they either have low solubility in neutral, well aerated soils, or they are present at insignificant concentrations in most non-industrial type sludges from domestic sewage treatment plants. Mercury was not found above 0.02 ppm in any soil sample in 1990.

Sludge Management

Sludges from non-industrial areas may contain large amounts of domestic wastes high in plant nutrients, including nitrogen, phosphorous, potassium, and others. Metals which may be harmful to plants and animals have been found in relatively low concentrations in Omaha's sludge. The organic matter in sewage sludge also may improve soil texture through proper land application.

Generally, when sewage sludge is applied to agricultural lands for a period of about 20 years, metals and salts build up to high concentrations in soils. High salt concentrations can cause soils to puddle and, thus, greatly reduce water intake (Mannering, et al. undated). When high metal concentrations have accumulated in soils, additional sludge applications may jeopardize plant health and consequently, the health of higher organisms in the food chains.

There is tremendous variability in the quality of sewage sludge and its potential impacts on soils, wildlife, and crop production when applied to agricultural land. Because of this variability, sludge application should be carefully monitored to be successful. Both the qualitative and quantitative information learned from this project will prove useful to the refuge, the City of Omaha, and to the agricultural community.

Crop Yields

Very few conclusions may be drawn from the crop yield data from this study. For corn yields, the control plot decreased in production from the baseline year. However, four other plots also decreased in productivity, including the commercial fertilizer plot, sludge applied every year and every other year, and compost applied every year. All soybean production decreased. It is likely that factors external to the controlled parameters were affecting productivity, most likely climatic.

Comparison of Fertilizer Methods

There are considerable differences between the processes for application of sludge, compost, and commercial fertilizer. Commercial fertilizer is by far the least expensive, when all costs for equipment, product, and labor are included. The timing of application is somewhat flexible, depending upon pre-plant or sidedress application. In addition, commercial fertilizer application generally requires one pass over the fields, so soil compaction is kept to a minimum. On the other hand, compost and sludge applications are both machinery and labor intensive. Composting requires the addition of a green plant product, a product many farmers will not have or could otherwise sell on the open market. For this project, a 53.7 acre cool-season grass field was mowed and chopped, or chopped standing, and transported to the site by stakebed trucks for composting purposes. Mixing required extensive use of equipment and time.

Application of compost also was a time-consuming process, requiring extensive use of machinery and labor. A front-end loader was needed to fill a manure spreader for spreading up to 12 loads per acre to meet soil fertilization requirements, assuming the average manure spreader used holds 160 to 220 bushels. Soil moisture requirements also could be limiting, and compaction usually was a problem in affected areas.

Sludge application was less intensive, but still considerably more so than commercial fertilizer. Once again, a front-end loader was required to haul up to five loads per acre to meet nitrogen requirements. Similar to composting, soil compaction and soil-moisture are a concern.

Unlike commercial fertilizer, sludge and composting require a separate site for piling, mixing, and storage, but it must be on or adjoining the croplands on which it will be applied; otherwise the considerable time and costs of application become prohibitive. Storage of sludge causes short-term sterilizations or "burning" of the soil, and storage on the cropping site would eliminate yields where piled. This is a general concern, since most farmers are not willing to give up any crop ground. In addition, the mixing process results in considerable compaction in and around the storage site.

Another aspect of sludge management is the requirement for it to be hauled to the site. For this project, the City of Omaha hauled the product via a contracted carrier. These trucks, with the sludge payload, weighed approximately 39 tons. Consequently, potential damage to access and refuge roads was a concern, and soil moisture conditions on the dumping site were often limiting. Also, extreme soil compaction on the site was inevitable. A private farmer would have to be concerned about the maneuverability of these big rigs on his lanes, with resulting road repairs, and soil compaction on and around the sludge pile site.

Public Interest

Throughout the study period, the plots were interpreted for the visiting public. A roadside turn-out exhibited two large interpretive panels which explained the sludge demonstration project. Since an average of over 300,000 people visit DeSoto annually, it can be assumed that considerable knowledge was exchanged on sludge management and composting.

Conclusions

The following addresses the objectives of the study.

1. Compare, evaluate, and document the impacts of sewage sludge, composted sewage sludge, and commercial fertilizer land applications on soil fertility, wildlife health, and agricultural production.

The use of sewage sludge from the City of Omaha had no measurable adverse effects on wildlife of the refuge during the short duration of this study. Metal concentrations in the sludge were low compared to that from industrial areas. The concentration of metals for the five treatment years showed no significant difference from the baseline year.

Crop yields indicate no significant differences between the treatments. No fertilization plots were comparable to four treatment plots.

If crop production is the goal of the soil amendment program, then results to date do not justify expanding the sewage sludge program to other refuge sites. However, the data may be inconclusive and additional years of studies, with more replication of treatments, are needed for greater assurance of results.

2. Evaluate the potential to expand sewage sludge and/or compost land applications to other refuge fields.

The use of sewage sludge and compost are very labor intensive. Its use on refuge lands would only be suitable if the material were brought to the fields without cost to the refuge, and machinery and labor were available to manipulate the material.

3. Develop guidelines suitable for use by refuge managers when considering sludge and/or compost land applications.

a. The sewage sludge must meet State and Environmental Protection Agency guidelines for disposal (40 CFR Part 257 et al., Fed. Reg. Feb 19, 1993). Subpart B - Land Application of the above Federal regulations are included as Appendix F. State and local permits may be needed.

b. Monitoring will be required for the permit, and may include residue analyses of soils for metals, possibly once per year.

c. Rate of application of sewage sludge is based on composition of the sludge material, nitrogen requirements, and the rate of build up of metals. Guidelines can be obtained from the Cooperative Extension Service or the State permitting agency.

d. Composting requires large machinery for mixing, like a front-end loader, road grader, dozer, and/or scarab. It also requires the addition of a green plant product and water. Sewage sludge requires a front-end loader for hauling and a method of spreading the material. Both require a separate site for piling, mixing, and storage.

4. Evaluate the windrow composting method using sewage sludge and plant residues.

Mixing the green plant product with the sludge was equipment and labor intensive. Water had to be hauled and added during several mixings to assist the decomposition process. However, once mixed, the decomposition process proceeded as planned.

5. Compare the ease, suitability, and resulting products of sludge land applications and composting options to aid the City of Omaha, Nebraska in planning future waste management.

The City would need to work closely with any farmer interested in sludge type soil amendments. The City would likely be required to haul the material to the site.

6. Compare time, equipment, and staff requirements associated with compost application with similar requirements for commercial fertilizer and sewage sludge applications.

Commercial fertilizer was by far the least expensive when all costs for equipment, product, and labor are included. Commercial fertilizer generally requires one pass over the fields, so compaction is kept to a minimum. Composting and sludge applications are both machinery and labor intensive process.

While no significant adverse impacts were found as a result of this six-year study, the site was removed from the refuge's agricultural program at the end of the period as part of a cropland reduction plan. It has subsequently been planted to native grasses to provide a large, interpreted prairie restoration adjacent to the refuge's auto tour route.

Recommendations

1. Since sewage sludge components vary from application to application, and metals are expected to build up in 15 to 20 years, a diligent monitoring program is recommended to stay ahead of any potential adverse affects which may result from use of sewage sludge as a soil amendment.

2. Additional years of studies, with more replication of treatments, are needed for greater assurance of monitoring results. Background information should be collected just before a project starts. Sludge/compost treatments should then be made for five years before the second round of evaluation begins. Evaluations would be made in five year intervals with land treatments occurring each year.

3. Groundwater analyses should be incorporated in future monitoring of sludge management studies. While the installation of lysimeters and wells is expensive, and the periodic analysis of water samples can be prohibitive, the information gained on the rate and amount of transport of leachate would seem to justify the funding. Leaching remained an unknown in this study.

4. The use of any fertilizers should be carefully examined for cost, need and results.

5. Doing large scale composting could reduce the cost. One large composting pad could provide material for many farms to make it affordable.

6. New landfill regulations limit yard waste deposits. Composting sludge with yard waste could make use of the material and provide farmers and gardeners with soil amendment materials.

Literature Cited

Beyer, W.N. 1990. Evaluating soil contamination. U.S. Fish Wildl. Serv., Biol. Rep. 90(2). 25pp.

Clark, M.L., D.G. Harvey, and K.J. Humphreys. 1981. Veterinary Toxicology. 2nd ed. London: Bailliere Tindall. 77pp.

Davies, P.H. 1986. Toxicology and chemistry of metals in urban runoff. In: B. Urbonas, T. Barnwell, D. Jones, L. Roesner, and L. Tucker, eds., Urban Runoff Quality, American Society of Civil Engineers, New York, NY. pp.60-78.

Eisler, R. 1986. Chromium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep 85 (1.6) .60 pp.

Eisler, R. 1988. Lead hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish Wildl. Serv. Biol. Rep. 85/1.14:1-134.

Irwin, R.J. 1988. Impacts of toxic chemicals on Trinity River fish and wildlife. Contaminants Report of the Fort Worth Field Office, U.S. Fish and Wildlife Service, Fort Worth, TX.

Jenkins, Dale W. 1981. Biological Monitoring of Toxic Trace Elements. EPA Report 600/S3-80-090:1-9.

Kepner, W.G. 1986. Lower Gila River Contaminant Study. Contaminants Report of the Phoenix Field Office, U.S. Fish and Wildlife Service, Phoenix, AZ.

Mannering, J.V., D.W. Nelson, and L.E. Sommers. 1974. Disposal of Sewage Sludge on Cropland. Agronomy Guide. Cooperative Extension Service, Purdue University, West Lafayette, IN. (URBAN)AY-202. 5pp.

National Library of Medicine. 1988. Hazardous Substances Data Bank (HSDB). In: "HSDB" electronic database as reproduced in the Tomes Plus (TM) CD-ROM data base Vol. 7, Micromedex Inc., Denver, Colorado.

New Jersey Department of Environmental Protection. 1987. Summary of approaches to soil cleanup levels. Division of Waste Management, 32 East Hanover Street, Trenton, New Jersey 08628.

O'Brien, T.F. 1987. Organochlorine and heavy metal contaminant investigation for the San Juan River basin, New Mexico, 1984. Contaminants Report of the Albuquerque Field Office, U.S. Fish and Wildlife Service, Albuquerque, N.M.

Schiffer, D.M. 1989. Effects of highway runoff on the quality of water and bed sediments of two wetlands in central Florida. USGS Water-Resources Investigations Report 88-4200, Depart. of the Interior, US Geological Survey, Tallahassee, FL 63 pp.

Sommers, L.E., Darrell W. Nelson, and Clifford D. Spies. 1980. Use of sewage sludge in crop production. Energy management in agriculture. Cooperative Extension Service, Purdue University, West Lafayette, IN. (FERTILITY)AY-240. 12pp.

U.S. Department of Health and Human Services and **U.S. Environmental Protection Agency.** 1987. Notice of the first priority list if hazardous substances that will be the subject of toxicological profiles. Federal Register. 52:12866-12874.

Walsh, D.F., B.L. Berger, and J.R. Bean. 1977. Mercury, arsenic, lead, cadmium, and selenium residues in fish. 1971-1973 National Pesticide Monitoring Program. Pestic. Monit. J. 11:5-34

Appendix A

Table A-1. Analytical results (ICP scan) for inorganic elements in composited soil samples collected at DeSoto National Wildlife Refuge, 1985.

Metal	SOIL SAMPLE SITES (ppm dry weight)												
	1-E	1-M	1-W	2-E	2-M	2-W	2-W*	3-E	3-M	3-W	4-E	4-M	4-W
Aluminum	6240	7620	5640	6210	6130	5370	5600	5840	5200	6280	4980	3300	4900
Boron	3.0	4.0	4.0	3.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	<2.0	<4.0
Barium	220	234	216	225	218	234	231	213	230	250	192	174.0	207
Beryllium	0.44	0.52	0.40	0.44	0.43	0.39	0.39	0.40	0.37	0.43	0.33	0.22	0.26
Cadmium	0.5	0.6	0.4	0.6	<0.4	0.6	0.4	<0.40	0.4	0.40	<0.4	<0.4	<0.5
Chromium	3.8	13.0	<1.0	2.0	6.9	<1.0	2.0	1.0	8.3	21.0	5.7	5.6	24.0
Copper	11.0	13.0	10.0	13.0	8.9	9.0	9.1	10.0	7.8	10.0	6.0	3.4	5.5
Iron	12700	14000	12200	12900	12500	11800	11900	12100	11900	13100	11000	8370	10400
Mercury	0.05	0.05	<0.05	<0.05	<0.05	0.05	0.05	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Magnesium	6680	6570	6360	6760	6530	6190	6240	6170	5600	5500	4210	1970	3600
Manganese	413	433	361	431	347	342	340	362	317	377	256	167	244
Molybdenum	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Nickel	18.0	19.0	16.0	19.0	16.0	16.0	16.0	17.0	17.0	18.0	15.0	12.0	13.0
Lead	14.0	12.0	11.0	13.0	11.0	10.0	13.0	12.0	13.0	14.0	12.0	7.0	9.0
Strontium	43.9	47.4	40.7	45.6	41.5	38.5	38.0	42.7	36.4	37.5	27.9	21.1	27.4
Thallium	<10.0	<10.0	<10.0	<9.0	<10.0	<9.0	<9.0	<10.0	<10.0	<10.0	<9.0	<9.0	<10.0
Vanadium	15.0	18.0	14.0	15.0	15.0	13.0	14.0	13.0	14.0	16.0	13.0	9.9	13.0
Zinc	47.0	52.0	44.0	47.0	41.0	42.0	42.0	43.0	39.0	48.0	36.0	24.0	33.9

Samples from plots designated E or W are from the surface; samples designated M are from a 1-foot depth. * Duplicate.

Table A-1 cont. **Analytical results (ICP scan) for inorganic elements in composited soil samples collected at DeSoto National Wildlife Refuge, 1985.**

Metal	SOIL SAMPLE SITES (ppm dry weight)											
	5-E	5-M	5-W	6-E	6-M	6-W	6-W*	7-E	7-M	7-W	8-E	8-M	8-W
Aluminum	2970	4120	4670	5600	10600	7750	7960	5280	5680	7580	5120	5420	8830
Boron	<4.0	<4.0	<4.0	<4.0	5.0	<4.0	4.0	<4.0	<4.0	5.0	3.0	<2.0	5.8
Barium	125	158	177	230	233	207	204	224	250	214	223	213	203
Beryllium	0.15	0.29	0.29	0.33	0.58	0.47	0.50	0.32	0.33	0.53	0.35	0.39	0.62
Cadmium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.4	<0.4	<0.4	0.54
Chromium	9.3	18.0	14.0	16.0	33.0	9.8	19.0	15.0	21.0	15.0	14.0	18.0	13.0
Copper	2.8	6.6	7.6	7.6	15.0	13.0	14.0	8.6	7.8	12.0	6.9	8.0	18.0
Iron	8000	11100	10400	11800	16500	14700	15000	11600	11700	14200	11300	11900	16600
Mercury	<0.05	<0.05	0.22	0.41	0.67	<0.05	<0.05	<0.05	0.35	0.84	0.05	<0.05	0.05
Magnesium	2170	2730	3140	4800	6940	6440	6370	5550	5150	5930	5750	5620	6450
Manganese	165	248	307	327	474	493	485	359	336	449	319	350	637
Molybdenum	<1.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Nickel	11.0	17.0	16.0	16.0	21.0	20.0	20.0	16.0	15	18.0	14.0	15.0	23.0
Lead	6.0	9.0	8.0	11.0	12.0	12.0	12.0	10.0	8.0	10.0	10.0	10.0	10.0
Strontium	18.1	29.4	27.5	34.3	61.7	49.0	49.5	37.5	40.4	48.4	32.4	38.9	57.6
Thallium	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<7.0	<7.0	<7.0	<7.0
Vanadium	8.3	13.0	12.0	13.0	20.0	15.0	17.0	13.0	14.0	15.0	13.0	13.0	18.0
Zinc	26.0	33.0	35.8	39.8	56.0	52.6	53.7	39.6	38.1	50.2	39.3	40.3	64.2

Table A-1 cont. **Analytical results (ICP scan) for inorganic elements in composited soil samples collected at DeSoto National Wildlife Refuge, 1985.**

Metal	SOIL SAMPLE SITES (ppm dry weight)													
	9-E	9-M	9-W	10-E	10-M	10-W	10-W*	11-E	11-M	11-W	12-E	12-M	12-W	12-W*
Aluminum	7290	9130	8850	6080	5770	6740	8650	5310	3770	3760	7240	6270	9610	9270
Boron	4.0	5.0	3.0	<2.0	2.0	3.0	3.0	<2.0	<2.0	<2.0	4.0	<2.0	3.0	2.0
Barium	208	216	214	182	186	183	220	188	132	172	193	209	221	218
Beryllium	0.49	0.60	0.58	0.41	0.41	0.47	0.62	0.37	0.26	0.24	0.50	0.42	0.65	0.64
Cadmium	<0.4	0.4	<0.4	<0.4	<0.4	0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Chromium	3	4.0	13.0	9.2	9.0	10.0	13.0	7.9	5.4	5.4	11.0	11.0	13.0	13.0
Copper	12	16.0	16.0	10.0	10.0	11.0	18.0	9.1	5.6	3.8	14.0	9.0	16.0	16.0
Iron	14100	16400	16100	12300	12000	13100	16600	11400	8800	9000	142000	12000	16200	16100
Mercury	<0.05	<0.05	1.2	0.55	0.54	<0.05	1.4	0.58	<0.05	0.38	0.05	<0.05	1.3	1.3
Magnesium	6400	6280	6350	5320	5240	5250	6330	4360	3150	2960	5860	4960	6640	6630
Manganese	497	564	535	376	375	422	585	385	243	200	540	381	554	551
Molybdenum	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<1.0	<1.0	<2.0	<2.0	<2.0	<2.0
Nickel	19.0	21.0	21.0	16.0	16.0	18.0	22.0	16.0	13.0	12.0	19.0	16.0	19.0	21.0
Lead	10.0	10.0	10.0	10.0	10.0	10.0	20.0	10.0	7.0	9.0	10.0	10.0	10.0	10.0
Strontium	45.5	58.3	53.8	39.2	39.3	43.8	53.5	36.4	28.9	23.5	50.7	44.7	56.8	56.0
Thallium	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0
Vanadium	16.0	18.0	17.0	14.0	13.0	15.0	19.0	13.0	9.8	10.0	16.0	14.0	19.0	18.0
Zinc	51.6	59.2	59.8	44.6	43.6	47.3	63.6	41.9	28.0	29.0	51.4	39.5	58.4	57.9

Table A-1 cont. Analytical results (ICP scan) for metals in composited soil samples from DeSoto NWR, 1985.

Metal	SOIL SAMPLE SITES (ppm dry weight)					
	13-E	13-M	13-W	14-E	14-M	14-W
Aluminum	4530	5060	4660	4670	3050	5150
Boron	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Barium	170	162	199	189	117	225
Beryllium	0.32	0.37	0.33	0.33	0.23	0.37
Cadmium	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Chromium	6.6	7.6	6.9	6.9	4.5	8.9
Copper	6.1	7.8	6.2	6.8	3.0	6.9
Iron	9840	10600	10100	10300	7950	10700
Mercury	0.20	0.63	0.21	0.54	0.20	0.51
Magnesium	4130	5040	4140	4100	2260	4630
Manganese	274	330	273	284	180	315
Molybdenum	<2.0	<2.0	<2.0	<2.0	<1.0	<2.0
Nickel	12.0	14.0	14.0	13.0	11.0	14.0
Lead	10.0	10.0	10.0	9.0	<6.0	10.0
Strontium	29.2	35.0	28.2	29.7	20.0	0.07
Thallium	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0
Vanadium	12.0	12.0	12.0	12.0	9.1	13.0
Zinc	32.0	35.9	33.6	34.2	24.0	35.7

Table A-2. Analytical results (ICP scan) for inorganic elements in individual samples of deer liver from DeSoto National Wildlife Refuge for 1985.

Individual Deer Livers (ppm wet weight)											
	WTD-1	WTD-2	WTD-3	WTD-4	WTD-5	WTD-6	WTD-7	WTD-8	WTD-9	WTD-10	$\bar{X}$ [1]
Cadmium	0.031	0.088	<0.007	0.048	0.03	0.02	0.032	0.066	0.17* 0.18	0.10	0.065
Cobalt	0.02	0.057	<0.008	0.065	0.03	0.039	0.045	0.033	0.03**	0.053	0.041
Copper	3.83	31.5	0.66	7.04	59.6	4.67	33.6	35.1	48.7* 50.8	29.3	25.61
Iron	107	164	305	79.3	153	97.6	115	117	106* 107	188	143.29
Molybdenum	0.68	0.46	<0.04	0.58	0.52	0.89	0.65	0.43	0.60* 0.59	0.27	0.563
Nickel	<0.06	<0.06	<0.05	<0.06	<0.06	<0.06	<0.06	<0.05	<0.06**	<0.06	<0.06
Lead	<0.1	<0.1	<0.09	<0.1	<0.01	<0.1	<0.1	<0.1	<0.1**	<0.1	>0.1
Thallium	<0.2	<0.2	<0.1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2**	<0.2	<0.19
Vanadium	<0.009	<0.009	<0.007	<0.009	<0.009	<0.009	<0.008	0.02	<0.009**	<0.009	<0.009
Zinc	31.1	27.9	27.0	28.4	32.7	29.4	33.2	61.8	47.0* 47.1	38.2	35.68
Mercury	0.03	0.02	<0.02	0.02	0.03	0.02	<0.02	0.03	0.03**	0.02	
Aluminum	1.3	0.73	0.75	0.92	0.98	1.2	0.61	5.4	0.84	0.70	1.343
Beryllium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001**	<0.001	<0.001
Manganese	3.09	2.42	0.21	3.22	3.13	3.49	3.61	2.95	3.61**	3.33	2.91
Chromium	0.62	0.52	0.48	0.51	0.55	0.52	0.54	0.66	0.50* 0.53	0.62	0.555

Less than values were not used to calculate means except where less than values were the only values available.
Duplicate
Duplicate analyses performed with the same result.

Table A-3. Analytical results (ICP scan) for inorganic elements in composite samples of pheasant livers from DeSoto National Wildlife Refuge for 1985.

	PHEASANT LIVER COMPOSITES (ppm wet weight)		
	PH-1[1]	PH-2[2]	PH-3[2]
Calcium	136	60	54.4, 56.1*, 52.8*
Phosphorus	2740	2860	2650, 2640*, 2660*
Potassium	3490	3520	3220**
Cadmium	0.055	0.030	0.068, 0.072*, 0.072*
Cobalt	0.042	0.035	0.02, 0.03*
Copper	5.36	4.70	4.52, 4.55*
Iron	213	190	173, 176*
Molybdenum	0.88	0.99	0.85, 0.87*
Nickel	<0.06	<0.06	<0.06**
Lead	<0.1	<0.1	0.03**
Thallium	<0.2	<0.2	<0.02**
Vanadium	<0.008	<0.008	<0.008**
Zinc	26.6	24.2	23.1, 23.4*
Mercury	0.02	0.02	<0.02**
Aluminum	0.056	0.96	0.2, 0.6*
Beryllium	<0.001	<0.001	<0.001**
Manganese	2.91	3.84	3.04, 2.98*
Chromium	0.44	0.52	0.53*

[1] Composite of two livers
[2] Composite of three livers
* Duplicate analyses
** Duplicate analyses performed with the same result

Table A-4. Inorganic analytical results on one composite sample of three squirrel livers from DeSoto National Wildlife Refuge collected in December 1985 - February 1986.

	CONCENTRATION (ppm wet weight)
Calcium	44
Phosphorus	2850
Potassium	3010
Cadmium	0.065
Cobalt	0.02
Copper	3.79
Iron	695
Molybdenum	0.53
Nickel	<0.06
Lead	<0.1
Thallium	<0.2
Vanadium	<0.009
Zinc	22.4
Mercury	<0.02

Table A-5. **Results of analysis for soil parameters in composited soil samples collected at DeSoto National Wildlife Refuge, 1985 (ppm dry weight).**

	Plot 1 1985			Plot 2 1985			Plot 3 1985			Plot 4 1985		
	1-E	1-M	1-W	2-E	2-M	2-W	3-E	3-M	3-W	4-E	4-M	4-W
Potassium K	-	-	1500	1900	1400	1400	1500	1100	1700	1100	650	1000
Exchangeable Ammonium nitrogen	18.0	7.0	15.0	15.0	12.0	9.0	20.0	14.0	26.0	14.0	5.0	6.0
Nitrate nitrogen	3.0	4.0	6.0	5.0	8.0	6.0	6.0	5.0	6.0	6.0	7.0	9.0
Total Kjeldahl N	900	520	824	880	780	948	848	628	1028	616	360	632
Organic nitrogen	882	513	809	865	768	939	828	614	1002	602	335	626
Exchangeable Sulfate sulfur	5.0	4.0	4.0	4.0	4.0	5.0	4.0	5.0	5.0	4.0	4.0	4.0
Organic matter %	2.1	1.1	2.0	2.0	1.5	1.6	1.6	1.3	2.1	1.4	0.9	1.1

	Plot 5 1985			Plot 6 1985			Plot 7 1985			Plot 8 1985		
	5-E	5-M	5-W	6-E	6-M	6-W	7-E	7-M	7-W	8-E	8-M	8-W
Potassium K	630	910	1300	1500	2300	2200	1700	1300	2100	1200	1200	2400
Exchangeable Ammonium nitrogen	6.0	9.0	13.0	17.0	19.0	4.0	40.0	18.0	23.0	16.0	7.0	18.0
Nitrate nitrogen	11.0	8.0	20.0	9.0	7.0	8.0	8.0	9.0	7.0	7.0	15.0	9.0
Total Kjeldahl N	604	332	976	912	948	1516	848	744	1028	688	560	1196
Organic nitrogen	402	599	963	743	1093	1514	808	726	1005	672	553	1178
Exchangeable Sulfate sulfur	4.0	6.0	6.0	8.0	6.0	4.0	4.0	5.0	4.0	7.0	4.0	4.0
Organic matter %	1.0	1.1	1.9	1.5	1.5	2.0	1.6	1.5	1.7	1.5	0.8	2.0

Samples from plots designated E or W are from the surface; samples designated M are from a 1-foot depth. * Duplicate.

Table A-5 cont. Results of analysis for soil parameters in composited soil samples collected at DeSoto National Wildlife Refuge, 1985 (ppm dry weight).

	Plot 9 1985			Plot 10 1985				Plot 11 1985			Plot 12 1985		
	9-E	9-M	9-W	10-E	10-E*	10-M	10-W	7-E	7-M	7-W	8-E	8-M	8-W
Potassium K	630	910	1300	1500	2300	2200	2500	1700	1300	2100	1200	1200	2400
Exchangeable Ammonium nitrogen	6.0	9.0	13.0	17.0	19.0	4.0	34.0	40.0	18.0	23.0	16.0	7.0	18.0
Nitrate nitrogen	11.0	8.0	20.0	9.0	7.0	8.0	8.0	8.0	9.0	7.0	7.0	15.0	9.0
Total Kjeldahl N	604	332	976	912	948	1516	1224	848	744	1028	688	560	1196
Organic nitrogen	402	599	963	743	1093	1514	1190	808	726	1005	672	553	1178
Exchangeable Sulfate sulfur	4.0	6.0	6.0	8.0	6.0	4.0	6.0	4.0	5.0	4.0	7.0	4.0	4.0
Organic matter %	1.0	1.1	1.9	1.5	1.5	2.0	2.4	1.6	1.5	1.7	1.5	0.8	2.0

	Plot 13 1985			Plot 14 1985		
	13-E	13-M	13-W	14-E	14-M	14-W
Potassium K	1300	1300	1200	1100	650	1500
Exchangeable Ammonium nitrogen	14.0	22.0	13.0	30.0	11.0	27.0
Nitrate nitrogen	12.0	5.0	14.0	6.0	8.0	7.0
Total Kjeldahl N	720	852	608	1136	360	696
Organic nitrogen	706	830	595	1106	349	669
Exchangeable Sulfate sulfur	9.0	4.0	4.0	4.0	4.0	9.0
Organic matter %	1.5	1.6	1.3	2.0	0.9	1.5

Appendix B

Table B-1. Analytical results (ICP scan) for metals in composited soil samples from DeSoto National Wildlife Refuge, 1987.

Metal	SOIL SAMPLE SITES (ppm dry weight)														
	1E	1M	1W	2E	2M	2W	3E	3M	3W	4E	4M	4W	5E	5M	5W
Aluminum	4410	3900	4530	4490	4140	4390	4540	3410	4200	2920	2290	3650	1960	2860	3680
Boron	5.3	4.1	3.8	5.3	<4.6	4.5	4.9	3.7	3.5	3.7	2.8	2.8	2.4	3.3	2.9
Barium	185	170	175	178	164	180	171	144	170	118	78	101	80.	90	109
Beryllium	0.27	0.28	0.29	0.30	0.26	0.28	0.31	0.22	0.25	0.22	0.15	0.20	0.14	0.21	0.22
Cadmium	<0.5	<0.50	<0.5	<.50	<0.5	<0.5	<0.5	<0.5	<0.5	0.53	<0.50	<0.5	<0.50	<0.5	<0.5
Chromium	8.4	7.5	8.5	20.	8.6	15	8.5	7.3	7.9	11	4.7	9.8	6.9	6.0	6.6
Copper	11	8.9	9.6	15.	9.4	10	11	5.8	9.1	6.0	3.5	7.1	3.0	5.1	7.4
Iron	10600	10100	10900	10800	10400	10700	10700	95600	10500	8370	7190	9190	6740	8740	9110
Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Magnesium	6920	6640	6040	6740	6400	5920	6470	5760	5480	3890	1910	3350	2240	2810	2720
Manganese	461	403	368	458	381	362	444	302	374	257	206	297	179	261	311
Molybdenum	<2.0	<2.0	3.5	<2.	<2.0	3.3	<2.0	<2.0	2.9	<2.0	<2.0	2.7	<2.0	<2.0	3.0
Nickel	16	14	14	16	15	14	15	13	14	12	11	12	11	14	13
Lead	8.0	5.5	12	12	5.9	13	<5.0	<5.0	7.4	8.3	<5.0	9.9	<5.0	5.0	6.7
Strontium	34	37	33	38.0	34	30.2	36	28	28	18.	15	21	12	19	21
Thallium	<.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Vanadium	12	10	13	130	11	13	11	9.9	12	8.7	6.9	9.7	6.7	8.4	10
Zinc	48.	65.2	44	59.	44.7	52	47.	35	44	36.	25	39	25	32	34

Samples designated E or W are from the surface; samples designated M are from a 1-foot depth.

Table B-1 cont. **Analytical results (ICP scan) for metals in composited soil samples from DeSoto National Wildlife Refuge, 1987.**

Metal	SOIL SAMPLE SITES (ppm dry weight)														
	6E	6M	6W	7E	7M	7W	8E	8M	8W	9E	9M	9W	10E	10M	10W
Aluminum	4080	5370	6560	4490	4430	6930	3690	3400	4641	5130	2810	7290	4560	4420	7560
Boron	4.7	5.9	5.7	4.4	4.4	3.8	4.4	3.2	5.4	5.9	2.6	4.4	5.2	4.0	4.8
Barium	132	166	179	151	156	185	155	143	191	172	143	192	144	139	200
Beryllium	0.25	0.36	0.42	0.27	0.28	0.41	0.27	0.22	0.45	0.34	0.20	0.47	0.29	0.27	0.47
Cadmium	<0.5	<0.50	<0.5	<.50	<0.5	<0.5	<0.5	<0.5	<0.5	0.80	<0.50	<0.5	<0.50	<0.5	<0.56
Chromium	19	9.5	23	16	8.7	16	7.3	6.3	12	29	6.4	31	15	7.9	20
Copper	11	13	17	9.7	8.7	14	8.3	6.9	18	17	5.5	21	11	11	19
Iron	10100	12100	13300	10200	10400	13300	9830	9290	14400	12200	8380	14000	10600	10500	14500
Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Magnesium	4880	6310	5210	5590	5540	5620	6250	5480	6410	6360	4950	6150	5630	5330	5870
Manganese	364	506	504	391	399	503	403	341	673	542	282	638	434	427	633
Molybdenum	<2.0	<2.0	4.2	<2.0	<2.0	3.8	<2.0	3.1	4.1	<2.0	3.1	4.4	<2.0	3.3	4.8
Nickel	14	16	18	15	15	17	13	13	20	17	12	20	17	15	21
Lead	10	<5.0	20	11	<5.0	13	7.5	6.1	13	17	5.7	25	6.1	8.5	19
Strontium	29	51	43	31	34	45	27	31	52	40	26	51	33	33	48
Thallium	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Vanadium	9.8	12	15	13	11	15	10	10	16	13	9.3	15	11	12	16
Zinc	54	50	67	50	44	59	42	34	64	71	31	81	52	44	72

Table B-1 cont. Analytical results (ICP scan) for metals in composited soil samples from DeSoto National Wildlife Refuge, 1987.

Metal	SOIL SAMPLE SITES (ppm dry weight)											
	11E	11M	11W	12E	12M	12W	13E	13M	13W	14E	14M	14W
Aluminum	4210	2200	2690	5390	4880	6260	3230	2860	3430	4120	2520	3790
Boron	4.6	1.9	2.7	5.9	4.8	5.6	4.0	2.8	2.9	4.6	2.4	3.1
Barium	91	83	109	158	171	194	109	108	129	131	104	132
Beryllium	0.26	0.15	0.16	0.34	0.35	0.39	0.20	0.20	0.21	0.29	0.16	0.23
Cadmium	<0.5	<0.50	<0.5	<.50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.50	<0.5
Chromium	8.7	4.7	13	17	83	21	8.0	5.9	7.1	7.9	5.1	6.9
Copper	8.7	4.4	6.0	14	84	17	6.5	6.7	7.0	8.5	4.7	7.3
Iron	10700	7180	7780	11600	11500	12800	8680	7900	8700	10100	7560	9430
Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Magnesium	4360	2630	2770	5610	5970	6180	4060	4470	4100	4650	4270	3700
Manganese	398	227	217	500	498	538	296	330	289	362	228	337
Molybdenum	<2.0	2.5	2.4	<2.0	3.9	3.5	<2.0	2.9	5.8	<2.0	2.2	2.9
Nickel	3.4	11	11	16	16	17	12	11	12	14	11	13
Lead	<5.0	6.5	8.2	7.6	12	12	5.1	9.1	6.4	9.3	5.7	6.9
Strontium	21	18	16	43	42	46	21	25	22	25	16	24
Thallium	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Vanadium	9.2	7.9	8.7	12	13	14	9.0	9.0	10	10	8.2	10
Zinc	30	25	37	57	51	64	35	29	34	41	26	36

Table B-2. Analytical results (ICP scan) for metals in pheasant liver and deer liver from DeSoto National Wildlife Refuge, 1987.

Metal	PHEASANT LIVER SAMPLES			DEER LIVER SAMPLES									
	1	2	3	1	2	3	4	5	6	7	8	9	10
Aluminum	54.7	<2	<2	<2	<2	<2	5.0	30.1	16	11.8	6.0	9.2	5.6
Barium	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.65	0.23	0.43	0.21	0.21	<0.2
Beryllium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Boron	8.7	<1.4	<1.4	<1.4	5.1	7.0	7.0	4.1	25.8	9.8	9.3	16.0	17.2
Cadmium	<0.5	1.1	0.73	<0.5	<0.5	<0.5	0.76	0.92	0.92	<0.5	0.83	<0.5	0.75
Chromium	0.66	0.79	0.61	0.84	0.62	0.86	0.67	1.4	0.46	1.2	0.60	0.73	0.59
Copper	19.8	22.9	16.4	103	95.2	71.6	119	135	37	188	104	81.1	134
Iron	675	1100	1780	399	347	549	360	303	639	557	490	577	577
Lead	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
Magnesium	884	785	834	538	572	575	552	625	532	597	607	625	662
Manganese	15.6	11.5	13.2	12.6	13.4	10.5	12.4	12	9.9	12.4	9.4	4.7	11.7
Molybdenum	3.5	3.9	3.3	<2	2.2	<2	<2	<2	<2	3.6	<2	<2	<2
Nickel	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Strontium	<1	<1	<1	<1	<1	<1	<1	<1	1.4	<1	<1	<1	<1
Thallium	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Tin	<2	<2	<2	<2	<2	5.4	<2	<2	<2	<2	<2	<2	<2
Vanadium	<0.3	<0.3	<0.3	<0.3	<0.3	0.43	<0.3	<0.3	<0.3	0.60	<0.3	<0.3	<0.3
Zinc	112	105	107	107	107	104	104	150	104	222	145	271	149
Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table B-3. Analytical results (ICP scan) for metals in composited samples of mice from DeSoto National Wildlife Refuge, 1987.

Metal	MICE - WHOLE BODY SAMPLES													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Aluminum	973	1360	1750	745	349	845	796	1070	1210	1730	705	520	1660	1250
Barium	6.7	6.8	12.2	9.9	7.1	8.5	10.0	7.6	9.6	9.8	9.6	11.8	9.9	9.6
Beryllium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Boron	<1.4	<1.4	19.2	33.4	32.2	<1.4	20.8	<1.4	<1.4	<1.4	<1.4	<1.4	<1.4	8.2
Cadmium	<0.5	<0.3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chromium	2.0	1.6	2.1	2.5	1.1	1.5	1.8	2.2	1.5	2.0	1.3	1.5	2.6	1.6
Copper	12.9	11	13.8	10.9	9.2	10.1	12.9	11.9	11.6	12.2	10.8	10.6	12.4	10.8
Iron	260	273	366	291	236	222	312	262	323	349	267	282	334	246
Lead	5.3	<5	<5	6.3	<5	<5	<5	7.8	<5	6.0	<5	<5	9.7	<5
Magnesium	1340	1410	1370	1460	1290	1370	1330	1450	1330	1660	1340	1340	1430	1400
Manganese	13.3	18.6	22.4	13.5	8.5	11.9	13.4	15.8	17.8	26.8	13.1	10.9	23.3	17
Molybdenum	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Nickel	<2	<2	<2	<2	<2	<2	<2	<2	2	<2	<2	<2	2.6	<2
Strontium	20.2	16.8	21.4	23.4	19.8	26.2	20	19.0	22.0	22.6	19.1	18.6	23.1	21.9
Thallium	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Tin	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	2.6	2.7
Vanadium	0.57	0.31	0.54	0.97	<0.3	<0.3	3.3	0.63	0.34	0.93	<0.3	<0.3	1.5	<0.3
Zinc	115	107	108	108	96.9	110	115	121	102	108	98.4	114	102	103
Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Table B-4. Results of analysis for soil parameters in composited soil samples collected at DeSoto National Wildlife Refuge, 1987.

	Plot 1			Plot 2			Plot 3			Plot 4			Plot 5			Plot 6			Plot 7		
	1E	1M	1W	2E	2M	2W	3E	3M	3W	4E	4M	4W	5E	5M	5W	6E	6M	6W	7E	7M	7W
% Organic Matter	2.2	2.2	2.1	1.3	1.0	1.9	1.8	1.7	2.5	2.5	1.6	2.6	1.6	1.9	1.2	1.1	1.0	.7	1.5	1.6	1.4
Cl ppm	127.6	142.4	160.9	115.4	92.8	126.7	129.8	110.4	86.5	90.1	6.0	79.3	142.9	86.5	125.8	92.4	145.6	143.4	173.6	83.4	151.9
Na ppm	714	724	870	607	490	675	675	812	460	470	490	441	730	421	656	480	724	724	821	460	763
pH	7.9	7.9	7.9	8.0	8.0	7.9	8.0	8.0	7.8	7.9	8.1	7.9	8.1	8.1	8.2	8.3	8.4	8.3	8.3	8.1	8.1
CEC meq/100g	39.1	28.0	24.2	20.0	24.5	33.1	27.8	37.5	39.8	26.2	32.4	28.3	24.2	20.3	18.1	23.4	27.2	32.6	28.7	30.8	36.1
NH_4-N ammoniacal Nitrogen ppm	3.13	2.7	2.8	1.95	2.0	2.2	2.1	2.0	1.4	1.9	1.9	2.0	1.8	2.0	1.8	1.3	1.6	1.1	<1.1	1.5	1.9
Nitrate NO_3-N ppm	16.2	16.4	12.8	4.1	2.3	14.0	12.0	8.4	20.4	16.2	9.0	20.4	10.4	10.4	6.5	7.0	5.0	3.4	6.2	9.6	9.6
TKN Total Nitrogen ppm	1000	1100	1030	740	514	1030	934	898	57	1300	1060	1530	845	1050	574	547	508	453	737	868	836

Samples designated E or W are from the surface; samples designated M are from a [illegible]-foot depth

Table B-4 cont. **Results of analysis for soil parameters in composited soil samples collected at DeSoto National Wildlife Refuge, 1987.**

	Plot 8			Plot 9			Plot 10			Plot 11		
	8E	8M	8W	9E	9M	9W	10E	10M	10W	11E	11M	11W
% Organic Matter	1.1	.9	1.9	.8	2.0	1.2	.8	1.6	1.5	1.9	1.5	1.8
Cl ppm	199.7	151.5	97.8	109.6	102	164.1	136.1	141.5	169.1	106.8	193.4	131.6
Na ppm	958	710	529	499	548	792	665	802	880	568	734	656
pH	8.3	8.3	8.0	8.4	7.9	8.1	8.1	7.9	7.7	7.9	7.8	7.8
CEC meq/100g	34.4	32.1	41.0	27.7	21.6	31.0	30.2	35.2	21.3	21.0	21.4	21.2
NH_4-N ammoniacal Nitrogen ppm	1.8	1.7	2.1	1.7	2.2	1.9	1.4	2.0	2.3	2.0	2.2	2.3
Nitrate NO_3-N ppm	6.0	3.9	7.2	2.3	18.3	4.6	4.3	10.9	14.4	11.4	6.5	11.3
TKN Total Nitrogen ppm	562	493	1180	368	1210	644	676	1400	2190	1560	1180	1330

	Plot 12			Plot 13			Plot 14		
	12E	12M	12W	13E	13M	13W	14E	14M	14W
% Organic Matter	2.7	2.3	2.7	3.2	3.2	1.3	3.0	1.5	1.7
Cl ppm	85.63	79.77	67.14	76.61	86.98	119	82.9	148.8	158.2
Na ppm	490	431	382	460	529	675	509	734	821
pH	7.8	8.0	7.9	7.8	7.8	7.7	7.9	8.0	7.9
CEC meq/100g	32.2	17.2	29.8	21.4	30.4	31.6	33.3	22.1	32.3
NH_4-N ammoniacal Nitrogen ppm	2.4	2.7	1.9	2.6	2.6	2.4	2.7	2.1	2.8
Nitrate NO_3-N ppm	17.2	13.0	13.0	22.8	12.0	9.2	25.6	11.2	11.1
TKN Total Nitrogen ppm	2420	2180	2640	3450	3660	1820	3120	1980	1750

Appendix C

Table C-1. Analytical results (ICP scan) for metals in composited soil samples from DeSoto National Wildlife Refuge, 1990 - 1991.

Metal	SOIL SAMPLE SITES (ppm dry weight)											
	1E	1M	1W	2E	2M	2W	3E	3M	3W	4E	4M	4W
Aluminum	6960	12200	6400	8760	7810	6440	8180	5900	7130	6320	3810	5290
Boron	4	3	<2	3	<2	<2	4	<2	2	<2	<2	<2
Barium	213	222	216	251	238	236	242	214	246	235	316	188
Beryllium	0.43	0.74	0.44	0.51	0.44	0.40	0.51	0.4	0.45	0.37	.2	0.31
Cadmium	0.3	0.4	0.3	0.89	28.5	0.4	0.5	<0.2	0.4	0.2	.2	0.4
Chromium	12	17	11	65	15	26	21	9.9	24	14	7.8	27
Copper	12	20.7	11	22.7	11	11	14	8.1	12	7.4	4.8	9.0
Iron	12700	18300	12200	14100	12300	11500	13400	11400	12500	10500	9140	10100
Mercury	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.02
Magnesium	6500	6920	6380	6730	6600	6150	6680	5840	5800	4170	2380	2900
Manganese	438	680	371	460	368	331	436	302	361	258	194	223
Molybdenum	<0.9	<1	<1	<1	<1	<1	<1	<1	<0.9	<0.9	<1	<0.9
Nickel	17	23	16	19	16	15	17	15	16	13	14	13
Lead	10	15	10	27	10	15	14	9	13	10	7	12
Strontium	39.5	70.8	37.1	50.0	44.7	36.2	45.8	39.7	38.3	27.2	21.8	23.9
Thallium	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6
Vanadium	18	24	17	22	20	18	21	17	19	17	12	14
Zinc	48.7	65.2	46.0	84.5	44.7	49.9	55.7	37.1	53.3	39.5	26.6	47.9

Samples designated E or W are from the surface; samples designated M are from a 1-foot depth.

Table C-1 cont. **Analytical results (ICP scan) for metals in composited soil samples from DeSoto National Wildlife Refuge, 1990 - 1991.**

Metal	SOIL SAMPLE SITES (ppm dry weight)											
	5E	5M	5W	6E	6M	6W	7E	7M	7W	8E	8M	8W
Aluminum	3550	9660	5590	5970	10500	10400	6480	3550	5450	8260	4340	5640
Boron	3	<2	178	<2	<2	<2	<2	<2	3	6	<2	3
Barium	156	219	189	211	224	237	251	192	209	205	218	206
Beryllium	0.2	0.53	.34	.36	.61	.57	.37	0.2	.37	.55	.2	.34
Cadmium	0.3	0.3	.3	.6	.3	.5	.4	<.2	.4	.5	<.2	.3
Chromium	15	14	17	63	15	42	40	6.6	24	12	7.3	9.1
Copper	4.7	12	8.1	15	17	19	12	3.9	13	19	5.6	10
Iron	8460	14200	10500	12100	16100	15600	11800	9280	11600	15500	9800	11700
Mercury	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.02	0.01	0.01
Magnesium	2360	4940	3020	4280	6780	6210	4890	3660	5210	6260	5170	5860
Manganese	163	419	270	305	533	468	326	258	404	641	267	408
Molybdenum	<1	<.9	<.9	<1	<1	<1	<1	<.9	<1	<1	<1	<1
Nickel	12	18	15	16	22	20	15	13	16	22	13	16
Lead	9	10	10	18	12	19	18	7	16	14	7	9
Strontium	18	48.3	26.4	32.9	62.8	51	32.5	25.8	36.6	51.5	35.2	35.5
Thallium	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6
Vanadium	11	22	15	15	22	21	17	12	16	23	14	16
Zinc	31	46.8	38.9	64.2	57.7	72.4	55.3	29.5	52.7	60.3	30.6	43.6

Table C-1 cont. Analytical results (ICP scan) for metals in composited soil samples from DeSoto National Wildlife Refuge, 1990 - 1991.

Metal	SOIL SAMPLE SITES (ppm dry weight)											
	9E	9M	9W	10E	10M	10W	11E	11M	11W	12E	12M	12W
Aluminum	7790	4480	6180	7970	4250	3890	3600	3830	3350	8300	7230	6810
Boron	4	3	5	4	<2	<2	<2	<2	<2	6	4	4
Barium	231	223	214	230	195	172	217	176	152	234	201	210
Beryllium	.52	.3	.40	.57	.3	.3	.2	.3	0.2	.57	.47	.44
Cadmium	.82	<0.2	.7	.6	<.2	.3	.3	<.2	.6	.6	.4	.5
Chromium	68	9.4	63	41	8.3	28	31	9.1	59	43	14	34
Copper	23.7	7.5	20.3	22.2	7.7	9.3	8.1	6.3	13	21.8	17	18
Iron	15600	10700	13500	15900	9520	9650	8370	10400	9870	15900	14200	13800
Mercury	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Magnesium	6030	4980	5250	5950	3590	3620	2720	3330	3010	6290	6190	5720
Manganese	563	320	454	591	290	249	187	255	245	581	559	495
Molybdenum	<1	<1	<0.9	<1	<.9	<.9	<1	<1	<1	<1	<1	<1
Nickel	21	15	18	22	12	13	12	15	14	21	19	18
Lead	21	9	21	19	7	10	13	9	17	19	10	17
Strontium	50.7	35.5	41.2	49.5	30.2	23.9	24.9	26.1	25.2	52.2	61.4	49
Thallium	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6
Vanadium	20	15	18	20	13	13	12	14	11	21	19	19
Zinc	82.9	34.7	75.2	76	31.5	45.5	41.9	33.4	61.1	75.8	52.9	63.3

Table C-1 cont. **Analytical results (ICP scan) for metals in composited soil samples from DeSoto National Wildlife Refuge, 1990 - 1991.**

Metal	SOIL SAMPLE SITES (ppm dry weight)					
	13E	13M	13W	14E	14M	14W
Aluminum	3870	3680	4430	4900	3390	2940
Boron	<2	<2	<2	4	2	2
Barium	228	159	185	189	162	154
Beryllium	.3	.3	.3	0.35	0.2	.2
Cadmium	.4	<.2	<.2	<.3	<.3	<.3
Chromium	35	6.5	17	7.7	5.1	4.7
Copper	9.8	7	8.2	8.1	4.4	4.1
Iron	9760	8690	9690	10200	8130	7710
Mercury	0.02	0.02	0.02	0.02	0.02	0.02
Magnesium	3370	4130	3900	4570	3350	2690
Manganese	240	280	287	300	186	181
Molybdenum	<1	<1	<1	<1	<1	<1
Nickel	12	12	13	13	10	11
Lead	13	7	10	9	6	5
Strontium	24.7	30	26.2	26.6	19.4	17
Thallium	<6	<6	<6	<6	<6	<6
Vanadium	13	12	14	14	11	9.8
Zinc	43.1	28.7	37.8	37.2	25.7	24.7

Table C-2. Analytical results (ICP scan) for metals in deer liver from DeSoto National Wildlife Refuge, 1990 - 91.

Metal	DEER LIVER SAMPLES									
	1	2	3	4	5	6	7	8	9	10
Aluminum	4	7	4	<3	6	<3	<3	7	3	<3
Boron	<2	<2	<2	<2	<2	2	<2	<2	<2	<2
Barium	.2	.2	.2	<0.1	.1	<.1	<.09	.36	.2	.2
Beryllium	<.1	<.1	<.09	<0.1	<.09	<.1	<.09	<.1	<.09	<.09
Cadmium	<.3	<.3	<.3	<.3	.3	<.3	<.3	<.3	.5	<.3
Chromium	<1	<1	<.9	<1	<.9	<1	<.9	<1	<.9	<.9
Copper	28.8	43.1	148	595	61.6	76.6	167	75.6	10.7	133
Iron	758	317	198	230	316	282	344	537	253	369
Mercury	0.006	0.006	0.006	0.005	0.006	0.006	0.005	0.006	0.006	0.006
Magnesium	502	308	488	457	490	521	478	388	505	463
Manganese	9.9	5.6	8.1	6.5	9.1	7.8	7.1	5.3	9.8	8.3
Molybdenum	1	1	2	2	2	1	2	<1	2	1
Nickel	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Lead	<4	<4	<4	4	<4	<4	<4	<4	<4	<4
Strontium	0.3	.35	.29	.1	.1	.2	.2	0.66	.2	.39
Thallium	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6
Vanadium	<.3	<.3	<.3	.3	<.3	<.3	<.3	<.3	<.3	<.3
Zinc	85.6	56.7	102	98.4	111	110	85.7	114	103	122

Table C-3. Analytical results (ICP scan) for metals in mice and pheasant livers from DeSoto National Wildlife Refuge, 1990 - 91.

Metal	MICE - WHOLE BODY SAMPLES														PHEASANT LIVER SAMPLES
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Aluminum	224	359	537	534	553	584	263	527	236	1490	229	238	177	247	18.1
Barium	11.2	10.3	11.9	6.75	6.66	14.4	7.43	12.7	6.62	12.1	4.05	12.1	12.7	11.0	.764
Beryllium	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1
Boron	1.93	1.8	2.52	2.02	1.84	4.04	1.88	2.42	.957	2.3	2.31	2.6	2.43	3.32	< .5
Cadmium	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1	< .1
Chromium	1.68	1.42	2.28	1.56	1.52	1.61	1.93	2.49	1.39	1.81	1.33	1.52	1.69	1.54	.953
Copper	9.14	4.24	7.28	11.5	7.82	9.72	5.98	11.1	6.09	9.07	7.66	7.96	7.6	7.22	13.4
Iron	280	125	258	218	219	198	154	290	155	250	182	181	181	277	689
Lead	4.5	< 1.5	< 1.5	2.36	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5	1.85	< 1.5	< 1.5	< 1.5	< 1.5
Magnesium	1240	1180	1430	1250	1360	1370	1310	1900	1370	1500	1180	1400	1580	1370	641
Manganese	10.1	9.47	9.12	13.8	12	10.8	6.94	13.1	11.5	195	8.99	11.3	10.6	12.2	12.5
Molybdenum	.557	.56	< .5	< .5	< .5	1.47	< .5	< .5	< .5	< .5	< .5	< .5	.937	.864	2.44
Nickel	< .5	< .5	< .5	< .5	< .5	< .5	.692	< .5	< .5	.633	.591	.540	< .5	< .5	< .5
Strontium	16.6	10.7	35.6	20.1	18.4	30.2	17.2	32.	20.4	25.8	12.6	28.4	29.3	24.9	.622
Vanadium	< .5	.606	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5	< .5
Zinc	86.8	58.1	960	87.9	86.4	95.9	85.4	102	95.	100	71.4	78.5	78.2	82.3	65.4
Mercury	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

Table C-4. **Results of analysis for soil parameters in composited soil samples collected at DeSoto National Wildlife Refuge, 1990 - 91.**

	Plot 1			Plot 2			Plot 3			Plot 4			Plot 5		
	1E	1M	1W	2E	2M	2W	3E	3M	3W	4E	4M	4W	5E	5M	5W
Organic Matter % Rate ENR #/A	2.0 H 91	1.5 M 79	1.9 M 88	2.6 H 103	0.9 M 65	1.6 M 82	1.9 M 88	0.5 L 55	2.0 H 91	1.2 M 73	0.9 M 65	1.8 M 86	1.3 M 75	0.8 L 63	1.4 M 77
P_1 ppm Rate	23 H	2 VL	24 H	99 VH	10 L	53 VH	39 VH	5 VL	53 VH	38 VH	17 M	87 VH	59 VH	5 VL	53 VH
P_2 ppm Rate	105 VH	9 L	107 VH	128 VH	68 VH	116 VH	120 VH	49 H	121 VH	105 VH	87 VH	129 VH	89 VH	83 VH	124 VH
K ppm Rate	422 VH	254 VH	309 VH	423 VH	143 H	243 VH	416 VH	119 M	348 VH	261 VH	124 VH	244 VH	229 VH	215 VH	387 VH
Mg ppm Rate	154 H	301 VH	148 M	145 M	104 M	115 M	139 M	92 L	130 M	125 M	113 M	110 H	99 M	138 M	120 M
Ca ppm Rate	1815 H	3215 VH	1909 H	1961 H	1914 VH	1808 VH	1962 H	1772 VH	1790 H	1470 H	1502 VH	1187 H	1128 H	1855 VH	1408 H
pH	7.9	8.1	8.0	7.7	8.0	7.9	7.9	8.2	7.9	8.0	8.1	7.5	7.7	8.1	7.9
CEC	11.4	19.2	11.6	12.1	10.8	10.6	12.0	9.9	10.9	9.1	8.8	7.5	7.1	11.0	9.0
% Base saturation K Mg Ca	9.5 11.2 79.3	3.4 13.0 83.6	6.8 10.7 82.5	9.0 10.0 81.0	3.4 8.0 88.6	5.9 9.0 85.1	8.9 9.6 81.5	3.1 7.7 89.2	8.2 9.9 81.9	7.4 11.5 81.1	3.6 10.7 85.6	8.4 12.3 79.4	8.3 11.7 80.0	5.0 10.5 84.5	11.0 11.1 77.9
Nitrate NO_3-N	2	6	8	32	16	10	13	4	13	11	4	17	11	5	9
Sulfur ppm Rate	17 M	15 M	11 L	24 H	11 L	17 M	26 VH	12 L	12 L	8 L	11 L	11 L	18 M	17 M	18 M
Ammoniacal Nitrogen ppm	3	<2	6	<2	<2	3	6	<2	6	6	<2	3	<2	3	3
Total Nitrogen %	0.10	0.07	0.09	0.16	0.04	0.09	0.11	0.11	0.02	0.06	0.02	0.08	0.05	0.04	0.0

Samples designated E or W are from the surface; samples designated M are from a 1-foot depth.

Table C-4 cont. **Results of analysis for soil parameters in composited soil samples collected at DeSoto National Wildlife Refuge, 1990 - 91.**

	Plot 6			Plot 7			Plot 8			Plot 9		
	6E	6M	6W	7E	7M	7W	8E	8M	8W	9E	9M	9W
Organic Matter % Rate ENR #IA	2.0 H 91	1.1 M 70	2.5 H 101	1.9 M 88	0.4 L 53	1.9 M 88	2.2 H 95	0.3 L 50	1.3 M 75	2.6 H 103	0.7 L 60	2.4 H 99
P_1 ppm Rate	118 VH	3 VL	87 VH	96 VH	10 L	64 VH	17 M	5 VL	17 M	93 VH	6 VL	107 VH
P_2 ppm Rate	134 VH	38 M	131 VH	123 VH	63 VH	130 VH	109 VH	51 H	102 VH	103 VH	49 H	137 VH
K ppm Rate	501 VH	255VH	712 VH	313 VH	162 VH	527 VH	499 VH	109 M	386 VH	430 VH	229 VH	448 VH
Mg ppm Rate	137 M	226 VH	188 H	133 H	90 L	153 M	179 H	80 L	137 M	204 H	222 H	205 H
Ca ppm Rate	1665 H	2667 VH	2074 H	1554 H	1783 VH	1903 H	2206 H	1627 VH	1777 H	2651 VH	2868 VH	2714 VH
pH	7.6	7.9	7.6	7.8	8.1	8.0	7.9	8.2	8.0	7.7	7.8	7.7
CEC	10.8	15.9	13.8	9.7	10.1	12.1	13.8	9.1	11.0	16.1	16.8	16.4
% Base saturation K Mg Ca	11.9 10.6 77.4	4.1 11.9 84.0	13.3 11.4 75.4	8.3 11.4 80.3	4.1 7.4 88.4	11.1 10.5 78.4	9.3 10.8 79.9	3.1 7.3 89.6	9.0 10.4 80.7	6.9 10.6 82.5	3.5 11.0 85.5	7.0 10.4 82.6
Nitrate NO_3-N	22	12	36	8	2	9	13	2	13	26	35	39
Sulfur ppm Rate	29 VH	23 H	26 VH	12 L	11 L	23 H	18 M	11 L	11 L	24 H	62 VH	26 VH
Ammonical Nitrogen ppm	3	3	8	3	<2	6	6	3	3	3	<2	8
Total Nitrogen %	0.14	0.05	0.16	0.10	0.03	0.11	0.12	0.01	0.08	0.17	0.03	0.17

T· ble C-4 R lts of lysis soi pa ramet rs com osi oil sam les collecte DeSot N Wildlif
Ref ge 990

	Plot 10			Plot 11			Plot 12			Plot 13			Plot 14
	10E	10M	10W	11E	11M	11W	12E	12M	12W	13E	13M	13W	14E
Organic Matter % Rate ENR #/A	2.7 H 105	0.6 L 58	1.7 M 84	1.9 M 88	0.6 L 58	2.4 H 99	2.9 H 109	1.2 M 73	2.6 H 103	1.2 M 73	0.7 L 60	1.6 M 82	1.7 M 84
P_1 ppm Rate	84 VH	34 VH	105 VH	119 VH	36 VH	118 VH	72 VH	5 VL	82 VH	94 VH	14 L	59 VH	24 H
P_2 ppm Rate	133 VH	88 VH	128 VH	131 VH	109 VH	123 VH	128 VH	25 M	132 VH	116 VH	85 VH	98 VH	101 VH
K ppm Rate	613 VH	139 H	313 VH	221 VH	225 VH	372 VH	785 VH	312 VH	772 VH	221 VH	195 VH	369 VH	358 VH
Mg ppm Rate	265 H	101 M	136 M	107 M	117 M	151 H	264 VH	284 VH	191 H	124 M	106 M	137 M	138 M
Ca ppm Rate	3131 H	1720 VH	1713 H	1429 VH	1776 VH	1781 H	2840 H	3011 VH	2315 H	1514 VH	1757 VH	1592 H	1724 H
pH	7.7	7.8	7.7	7.5	8.0	7.6	7.8	8.1	7.7	7.6	8.1	7.9	8.0
CEC	19.4	9.8	10.5	8.6	10.4	11.1	18.4	18.2	15.1	9.2	10.2	10.0	10.7
% Base saturation K Mg Ca	8.1 11.4 80.6	3.6 8.6 87.8	7.6 10.8 81.6	6.6 10.4 83	5.5 9.3 85.1	8.6 11.3 80.1	10.9 11.9 77.1	4.4 13.0 82.6	13.1 10.5 76.4	6.2 11.3 82.6	4.9 8.7 86.4	9.4 11.4 79.2	8.6 10.8 80.7
Nitrate NO_3-N	23	6	20	23	6	27	29	29	25	8	4	12	9
Sulfur ppm Rate	29 VH	35 VH	23 H	12 L	18 M	21 H	33 VH	33 VH	30 VH	53 VH	21 H	17 M	15 M
Ammonical Nitrogen ppm	8	<2	6	<2	<2	11	11	6	6	6	6	8	3
Total Nitrogen %	0.16	0.03	0.10	0.09	0.03	0.13	0.19	0.07	0.16	0.07	0.03	0.08	0.07

Appendix D

Appendix F

federal register

Friday
February 19, 1993

Part II

Environmental Protection Agency

40 CFR Part 257 et al.

Standards for the Use or Disposal of Sewage Sludge; Final Rules

applied to a unit area of land (e.g., gallons per acre).

(v) *Runoff* is rainwater, leachate, or other liquid that drains overland on any part of a land surface and runs off of the land surface.

(w) *Sewage sludge* is solid, semi-solid, or liquid residue generated during the treatment of domestic sewage in a treatment works. Sewage sludge includes, but is not limited to, domestic septage; scum or solids removed in primary, secondary, or advanced wastewater treatment processes; and a material derived from sewage sludge. Sewage sludge does not include ash generated during the firing of sewage sludge in a sewage sludge incinerator or grit and screenings generated during preliminary treatment of domestic sewage in a treatment works.

(x) *State* is one of the United States of America, the District of Columbia, the Commonwealth of Puerto Rico, the Virgin Islands, Guam, American Samoa, the Trust Territory of the Pacific Islands, the Commonwealth of the Northern Mariana Islands, and an Indian Tribe eligible for treatment as a State pursuant to regulations promulgated under the authority of section 518(e) of the CWA.

(y) *Store or storage of sewage sludge* is the placement of sewage sludge on land on which the sewage sludge remains for two years or less. This does not include the placement of sewage sludge on land for treatment.

(z) *Treat or treatment of sewage sludge* is the preparation of sewage sludge for final use or disposal. This includes, but is not limited to, thickening, stabilization, and dewatering of sewage sludge. This does not include storage of sewage sludge.

(aa) *Treatment works* is either a federally owned, publicly owned, or privately owned device or system used to treat (including recycle and reclaim) either domestic sewage or a combination of domestic sewage and industrial waste of a liquid nature.

(bb) *Wetlands* means those areas that are inundated or saturated by surface water or ground water at a frequency and duration to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

Subpart B—Land Application

§ 503.10 Applicability.

(a) This subpart applies to any person who prepares sewage sludge that is applied to the land, to any person who applies sewage sludge to the land, to sewage sludge applied to the land, and to the land on which sewage sludge is applied.

(b)(1) *Bulk sewage sludge.* The general requirements in § 503.12 and the management practices in § 503.14 do not apply when bulk sewage sludge is applied to the land if the bulk sewage sludge meets the pollutant concentrations in § 503.13(b)(3), the Class A pathogen requirements in § 503.32(a), and one of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8).

(2) The Regional Administrator of EPA or, in the case of a State with an approved sludge management program, the State Director, may apply any or all of the general requirements in § 503.12 and the management practices in § 503.14 to the bulk sewage sludge in § 503.10(b)(1) on a case-by-case basis after determining that the general requirements or management practices are needed to protect public health and the environment from any reasonably anticipated adverse effect that may occur from any pollutant in the bulk sewage sludge.

(c)(1) The general requirements in § 503.12 and the management practices in § 503.14 do not apply when a bulk material derived from sewage sludge is applied to the land if the derived bulk material meets the pollutant concentrations in § 503.13(b)(3), the Class A pathogen requirements in § 503.32(a), and one of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8).

(2) The Regional Administrator of EPA or, in the case of a State with an approved sludge management program, the State Director, may apply any or all of the general requirements in § 503.12 or the management practices in § 503.14 to the bulk material in § 503.10(c)(1) on a case-by-case basis after determining that the general requirements or management practices are needed to protect public health and the environment from any reasonably anticipated adverse effect that may occur from any pollutant in the bulk sewage sludge.

(d) The requirements in this subpart do not apply when a bulk material derived from sewage sludge is applied to the land if the sewage sludge from which the bulk material is derived meets the pollutant concentrations in § 503.13(b)(3), the Class A pathogen requirements in § 503.32(a), and one of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8).

(e) *Sewage sludge sold or given away in a bag or other container for application to the land.* The general requirements in § 503.12 and the management practices in § 503.14 do not apply when sewage sludge is sold or given away in a bag or other container for application to the land if the sewage sludge sold or given away in a bag or other container for application to the land meets the pollutant concentrations in § 503.13(b)(3), the Class A pathogen requirements in § 503.32(a), and one of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8).

(f) The general requirements in § 503.12 and the management practices in § 503.14 do not apply when a material derived from sewage sludge is sold or given away in a bag or other container for application to the land if the derived material meets the pollutant concentrations in § 503.13(b)(3), the Class A pathogen requirements in § 503.32(a), and one of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8).

(g) The requirements in this subpart do not apply when a material derived from sewage sludge is sold or given away in a bag or other container for application to the land if the sewage sludge from which the material is derived meets the pollutant concentrations in § 503.13(b)(3), the Class A pathogen requirements in § 503.32(a), and one of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8).

§ 503.11 Special definitions.

(a) *Agricultural land* is land on which a food crop, a feed crop, or a fiber crop is grown. This includes range land and land used as pasture.

(b) *Agronomic rate* is the whole sludge application rate (dry weight basis) designed:

(1) To provide the amount of nitrogen needed by the food crop, feed crop, fiber crop, cover crop, or vegetation grown on the land; and

(2) To minimize the amount of nitrogen in the sewage sludge that passes below the root zone of the crop or vegetation grown on the land to the ground water.

(c) *Annual pollutant loading rate* is the maximum amount of a pollutant that can be applied to a unit area of land during a 365 day period.

(d) *Annual whole sludge application rate* is the maximum amount of sewage sludge (dry weight basis) that can be applied to a unit area of land during a 365 day period.

(e) *Bulk sewage sludge* is sewage sludge that is not sold or given away in a bag or other container for application to the land.

(f) *Cumulative pollutant loading rate* is the maximum amount of an inorganic pollutant that can be applied to an area of land.

(g) *Forest* is a tract of land thick with trees and underbrush.

(h) *Land application* is the spraying or spreading of sewage sludge onto the land surface; the injection of sewage sludge below the land surface; or the incorporation of sewage sludge into the soil so that the sewage sludge can either condition the soil or fertilize crops or vegetation grown in the soil.

(i) *Monthly average* is the arithmetic mean of all measurements taken during the month.

(j) *Other container* is either an open or closed receptacle. This includes, but is not limited to, a bucket, a box, a carton, and a vehicle or trailer with a load capacity of one metric ton or less.

(k) *Pasture* is land on which animals feed directly on feed crops such as legumes, grasses, grain stubble, or stover.

(l) *Public contact site* is land with a high potential for contact by the public. This includes, but is not limited to, public parks, ball fields, cemeteries, plant nurseries, turf farms, and golf courses.

(m) *Range land* is open land with indigenous vegetation.

(n) *Reclamation site* is drastically disturbed land that is reclaimed using sewage sludge. This includes, but is not limited to, strip mines and construction sites.

§ 503.12 General requirements.

(a) No person shall apply sewage sludge to the land except in accordance with the requirements in this subpart.

(b) No person shall apply bulk sewage sludge subject to the cumulative pollutant loading rates in § 503.13(b)(2) to agricultural land, forest, a public contact site, or a reclamation site if any of the cumulative pollutant loading rates in § 503.13(b)(2) has been reached.

(c) No person shall apply domestic septage to agricultural land, forest, or a reclamation site during a 365 day period if the annual application rate in § 503.13(c) has been reached during that period.

(d) The person who prepares bulk sewage sludge that is applied to agricultural land, forest, a public contact site, or a reclamation site shall provide the person who applies the bulk sewage sludge written notification of the concentration of total nitrogen (as N on a dry weight basis) in the bulk sewage sludge.

(e)(1) The person who applies sewage sludge to the land shall obtain information needed to comply with the requirements in this subpart.

(2)(i) Before bulk sewage sludge subject to the cumulative pollutant loading rates in § 503.13(b)(2) is applied to the land, the person who proposes to apply the bulk sewage sludge shall contact the permitting authority for the State in which the bulk sewage sludge will be applied to determine whether bulk sewage sludge subject to the cumulative pollutant loading rates in § 503.13(b)(2) has been applied to the site since July 20, 1993.

(ii) If bulk sewage sludge subject to the cumulative pollutant loading rates in § 503.13(b)(2) has not been applied to the site since July 20, 1993, the cumulative amount for each pollutant listed in Table 2 of § 503.13 may be applied to the site in accordance with § 503.13(a)(2)(i).

(iii) If bulk sewage sludge subject to the cumulative pollutant loading rates in § 503.13(b)(2) has been applied to the site since July 20, 1993, and the cumulative amount of each pollutant applied to the site in the bulk sewage sludge since that date is known, the cumulative amount of each pollutant applied to the site shall be used to determine the additional amount of each pollutant that can be applied to the site in accordance with § 503.13(a)(2)(i).

(iv) If bulk sewage sludge subject to the cumulative pollutant loading rates in § 503.13(b)(2) has been applied to the site since July 20, 1993, and the cumulative amount of each pollutant applied to the site in the bulk sewage sludge since that date is not known, an additional amount of each pollutant shall not be applied to the site in accordance with § 503.13(a)(2)(i).

(f) When a person who prepares bulk sewage sludge provides the bulk sewage sludge to a person who applies the bulk sewage sludge to the land, the person who prepares the bulk sewage sludge shall provide the person who applies the sewage sludge notice and necessary information to comply with the requirements in this subpart.

(g) When a person who prepares sewage sludge provides the sewage sludge to another person who prepares the sewage sludge, the person who provides the sewage sludge shall provide the person who receives the sewage sludge notice and necessary information to comply with the requirements in this subpart.

(h) The person who applies bulk sewage sludge to the land shall provide the owner or lease holder of the land on which the bulk sewage sludge is applied notice and necessary information to comply with the requirements in this subpart.

(i) Any person who prepares bulk sewage sludge that is applied to land in a State other than the State in which the bulk sewage sludge is prepared shall provide written notice, prior to the initial application of bulk sewage sludge to the land application site by the applier, to the permitting authority for the State in which the bulk sewage sludge is proposed to be applied. The notice shall include:

(1) The location, by either street address or latitude and longitude, of each land application site.

(2) The approximate time period bulk sewage sludge will be applied to the site.

(3) The name, address, telephone number, and National Pollutant Discharge Elimination System permit number (if appropriate) for the person who prepares the bulk sewage sludge.

(4) The name, address, telephone number, and National Pollutant Discharge Elimination System permit number (if appropriate) for the person who will apply the bulk sewage sludge.

(j) Any person who applies bulk sewage sludge subject to the cumulative pollutant loading rates in § 503.13(b)(2) to the land shall provide written notice, prior to the initial application of bulk sewage sludge to a land application site by the applier, to the permitting authority for the State in which the bulk sewage sludge will be applied and the permitting authority shall retain and provide access to the notice. The notice shall include:

(1) The location, by either street address or latitude and longitude, of the land application site.

(2) The name, address, telephone number, and National Pollutant Discharge Elimination System permit number (if appropriate) of the person who will apply the bulk sewage sludge.

§ 503.13 Pollutant limits.

(a) Sewage sludge. (1) Bulk sewage sludge or sewage sludge sold or given away in a bag or other container shall not be applied to the land if the concentration of any pollutant in the sewage sludge exceeds the ceiling concentration for the pollutant in Table 1 of § 503.13.

(2) If bulk sewage sludge is applied to agricultural land, forest, a public contact site, or a reclamation site, either:

(i) The cumulative loading rate for each pollutant shall not exceed the cumulative pollutant loading rate for the pollutant in Table 2 of § 503.13; or

(ii) The concentration of each pollutant in the sewage sludge shall not exceed the concentration for the pollutant in Table 3 of § 503.13.

(3) If bulk sewage sludge is applied to a lawn or a home garden, the concentration of each pollutant in the

sewage sludge shall not exceed the concentration for the pollutant in Table 3 of § 503.13.

(4) If sewage sludge is sold or given away in a bag or other container for application to the land, either:

(i) The concentration of each pollutant in the sewage sludge shall not exceed the concentration for the pollutant in Table 3 of § 503.13; or

(ii) The product of the concentration of each pollutant in the sewage sludge and the annual whole sludge application rate for the sewage sludge shall not cause the annual pollutant loading rate for the pollutant in Table 4 of § 503.13 to be exceeded. The procedure used to determine the annual whole sludge application rate is presented in appendix A of this part.

(b) Pollutant concentrations and loading rates—sewage sludge.

(1) Ceiling concentrations.

TABLE 1 OF § 503.13.—CEILING CONCENTRATIONS

Pollutant	Ceiling concentration (milligrams per kilogram)[1]
Arsenic	75
Cadmium	85
Chromium	3000
Copper	4300
Lead	840
Mercury	57
Molybdenum	75
Nickel	420
Selenium	100
Zinc	7500

[1] Dry weight basis.

(2) Cumulative pollutant loading rates.

TABLE 2 OF § 503.13.—CUMULATIVE POLLUTANT LOADING RATES

Pollutant	Cumulative pollutant loading rate (kilograms per hectare)
Arsenic	41
Cadmium	39
Chromium	3000
Copper	1500
Lead	300
Mercury	17
Molybdenum	18
Nickel	420
Selenium	100
Zinc	2800

(3) Pollutant concentrations.

TABLE 3 OF § 503.13.—POLLUTANT CONCENTRATIONS

Pollutant	Monthly average concentrations (milligrams per kilogram)[1]
Arsenic	41
Cadmium	39
Chromium	1200
Copper	1500
Lead	300
Mercury	17
Molybdenum	18
Nickel	420
Selenium	36
Zinc	2800

TABLE 3 OF § 503.13.—POLLUTANT CONCENTRATIONS—Continued

[1] Dry weight basis.

(4) Annual pollutant loading rates.

TABLE 4 OF § 503.13.—ANNUAL POLLUTANT LOADING RATES

Pollutant	Annual pollutant loading rate (kilograms per hectare per 365 day period)
Arsenic	2.0
Cadmium	1.9
Chromium	150
Copper	75
Lead	15
Mercury	0.85
Molybdenum	0.90
Nickel	21
Selenium	5.0
Zinc	140

(c) Domestic septage.

The annual application rate for domestic septage applied to agricultural land, forest, or a reclamation site shall not exceed the annual application rate calculated using equation (1).

$$AAR = \frac{N}{0.0026} \quad \text{Eq. (1)}$$

Where:

AAR=Annual application rate in gallons per acre per 365 day period.

N=Amount of nitrogen in pounds per acre per 365 day period needed by the crop or vegetation grown on the land.

§ 503.14 Management practices.

(a) Bulk sewage sludge shall not be applied to the land if it is likely to adversely affect a threatened or endangered species listed under section 4 of the Endangered Species Act or its designated critical habitat.

(b) Bulk sewage sludge shall not be applied to agricultural land, forest, a public contact site, or a reclamation site that is flooded, frozen, or snow-covered so that the bulk sewage sludge enters a wetland or other waters of the United States, as defined in 40 CFR 122.2, except as provided in a permit issued pursuant to section 402 or 404 of the CWA.

(c) Bulk sewage sludge shall not be applied to agricultural land, forest, or a reclamation site that is 10 meters or less from waters of the United States, as defined in 40 CFR 122.2, unless otherwise specified by the permitting authority.

(d) Bulk sewage sludge shall be applied to agricultural land, forest, a public contact site, or a reclamation site at a whole sludge application rate that is equal to or less than the agronomic rate for the bulk sewage sludge, unless, in the case of a reclamation site, otherwise specified by the permitting authority.

(e) Either a label shall be affixed to the bag or other container in which sewage sludge that is sold or given away for application to the land, or an information sheet shall be provided to the person who receives sewage sludge sold or given away in an other container for application to the land. The label or information sheet shall contain the following information:

(1) The name and address of the person who prepared the sewage sludge that is sold or given away in a bag or other container for application to the land.

(2) A statement that application of the sewage sludge to the land is prohibited except in accordance with the instructions on the label or information sheet.

(3) The annual whole sludge application rate for the sewage sludge that does not cause any of the annual pollutant loading rates in Table 4 of § 503.13 to be exceeded.

§ 503.15 Operational standards—pathogens and vector attraction reduction.

(a) *Pathogens—sewage sludge.*

(1) The Class A pathogen requirements in § 503.32(a) or the Class B pathogen requirements and site restrictions in § 503.32(b) shall be met when bulk sewage sludge is applied to agricultural land, forest, a public contact site, or a reclamation site.

(2) The Class A pathogen requirements in § 503.32(a) shall be met when bulk sewage sludge is applied to a lawn or a home garden.

(3) The Class A pathogen requirements in § 503.32(a) shall be met when sewage sludge is sold or given away in a bag or other container for application to the land.

(b) *Pathogens—domestic septage.* The requirements in either § 503.32 (c)(1) or (c)(2) shall be met when domestic septage is applied to agricultural land, forest, or a reclamation site.

(c) *Vector attraction reduction—sewage sludge.*

(1) One of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(10) shall be met when bulk sewage sludge is applied to agricultural land, forest, a public contact site, or a reclamation site.

(2) One of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8) shall be met when bulk sewage sludge is applied to a lawn or a home garden.

(3) One of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8) shall be met when sewage sludge is sold or given away in a bag or other container for application to the land.

(d) *Vector attraction reduction—domestic septage.* The vector attraction reduction requirements in § 503.33(b)(9), (b)(10), or (b)(12) shall be met when domestic septage is applied to agricultural land, forest, or a reclamation site.

§ 503.16 Frequency of monitoring.

(a) *Sewage sludge.* (1) The frequency of monitoring for the pollutants listed in Table 1, Table 2, Table 3 and Table 4 of § 503.13; the pathogen density requirements in § 503.32(a) and in § 503.32(b)(2) through (b)(4); and the vector attraction reduction requirements § 503.33 (b)(1) through § 503.33(b)(8) shall be the frequency in Table 1 of § 503.16.

TABLE. 1 OF § 503.16.—FREQUENCY OF MONITORING—LAND APPLICATION

Amount of sewage sludge[1] (metric tons per 365 day period)	Frequency
Greater than zero but less than 290.	Once per year.
Equal to or greater than 290 but less than 1,500.	Once per quarter (four times per year).
Equal to or greater than 1,500 but less than 15,000.	Once per 60 days (six times per year).
Equal to or greater than 15,000.	Once per month (12 times per year).

[1] Either the amount of bulk sewage sludge applied to the land or the amount of sewage sludge received by a person who prepares sewage sludge that is sold or given away in a bag or other container for application to the land (dry weight basis).

(2) After the sewage sludge has been monitored for two years at the frequency in Table 1 of § 503.16, the permitting authority may reduce the frequency of monitoring for pollutant concentrations and for the pathogen density requirements in § 503.32 (a)(5)(ii) and (a)(5)(iii), but in no case shall the frequency of monitoring be less than once per year when sewage sludge is applied to the land.

(b) *Domestic septage.* If either the pathogen requirements in § 503.32(c)(2) or the vector attraction reduction requirements in § 503.33(b)(12) are met when domestic septage is applied to agricultural land, forest, or a reclamation site, each container of domestic septage applied to the land shall be monitored for compliance with those requirements.

(Approved by the Office of Management and Budget under control number 2040–0157)

§ 503.17 Recordkeeping.

(a) *Sewage sludge.* (1) The person who prepares the sewage sludge in § 503.10(b)(1) or (e) shall develop the following information and shall retain the information for five years:

(i) The concentration of each pollutant listed in Table 3 of § 503.13 in the sewage sludge.

(ii) The following certification statement:

"I certify, under penalty of law, that the Class A pathogen requirements in § 503.32(a) and the vector attraction reduction requirement in [insert one of the vector attraction reduction requirements in § 503.33(b)(1) through § 503.33(b)(8)] have been met. This determination has been made under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate the information used to determine that the pathogen requirements and vector attraction reduction requirements have been met. I am aware that there are significant penalties for false certification including the possibility of fine and imprisonment."

(iii) A description of how the Class A pathogen requirements in § 503.32(a) are met.

(iv) A description of how one of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8) is met.

(2) The person who derives the material in § 503.10 (c)(1) or (f) shall develop the following information and shall retain the information for five years:

(i) The concentration of each pollutant listed in Table 3 of § 503.13 in the material.

(ii) The following certification statement:

"I certify, under penalty of law, that the Class A pathogen requirements in § 503.32(a) and the vector attraction reduction requirement in [insert one of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8)] have been met. This determination has been made under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate the information used to determine that the pathogen requirements and the vector attraction reduction requirements have been met. I am aware that there are significant penalties for false certification including the possibility of fine and imprisonment."

(iii) A description of how the Class A pathogen requirements in § 503.32(a) are met.

(iv) A description of how one of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8) is met.

(3) If the pollutant concentrations in § 503.13(b)(3), the Class A pathogen requirements in § 503.32(a), and the vector attraction reduction requirements in either § 503.33 (b)(9) or (b)(10) are met when bulk sewage sludge is applied to agricultural land, forest, a public contact site, or a reclamation site:

(i) The person who prepares the bulk sewage sludge shall develop the following information and shall retain the information for five years.

(A) The concentration of each pollutant listed in Table 3 of § 503.13 in the bulk sewage sludge.

(B) The following certification statement:

"I certify, under penalty of law, that the pathogen requirements in § 503.32(a) have been met. This determination has been made under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate the information used to determine that the pathogen requirements have been met. I am aware that there are significant penalties for false certification including the possibility of fine and imprisonment."

(C) A description of how the pathogen requirements in § 503.32(a) are met.

(ii) The person who applies the bulk sewage sludge shall develop the following information and shall retain the information for five years.

(A) The following certification statement:

"I certify, under penalty of law, that the management practices in § 503.14 and the vector attraction reduction requirement in [insert either § 503.33 (b)(9) or (b)(10)] have been met. This determination has been made under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate the information used to determine that the management practices and vector attraction reduction requirements have been met. I am aware that there are significant penalties for false certification including fine and imprisonment."

(B) A description of how the management practices in § 503.14 are met for each site on which bulk sewage sludge is applied.

(C) A description of how the vector attraction reduction requirements in either § 503.33(b)(9) or (b)(10) are met for each site on which bulk sewage sludge is applied.

(4) If the pollutant concentrations in § 503.13(b)(3) and the Class B pathogen requirements in § 503.32(b) are met when bulk sewage sludge is applied to agricultural land, forest, a public contact site, or a reclamation site:

(i) The person who prepares the bulk sewage sludge shall develop the following information and shall retain the information for five years:

(A) The concentration of each pollutant listed in Table 3 of § 503.13 in the bulk sewage sludge.

(B) The following certification statement:

"I certify under, penalty of law, that the Class B pathogen requirements in § 503.32(b) and the vector attraction reduction requirement in [insert one of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8) if one of those requirements is met] have been met. This determination has been made under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate the information used to determine that the pathogen requirements [and vector attraction reduction requirements if applicable] have been met. I am aware that there are significant penalties for false certification including the possibility of fine and imprisonment."

(C) A description of how the Class B pathogen requirements in § 503.32(b) are met.

(D) When one of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8) is met, a description of how the vector attraction reduction requirement is met.

(ii) The person who applies the bulk sewage sludge shall develop the following information and shall retain the information for five years.

(A) The following certification statement:

"I certify, under penalty of law, that the management practices in § 503.14, the site restrictions in § 503.32(b)(5), and the vector attraction reduction requirements in [insert either § 503.33 (b)(9) or (b)(10), if one of those requirements is met] have been met for each site on which bulk sewage sludge is applied. This determination has been made under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate the information used to determine that the management practices and site restrictions [and the vector attraction reduction requirements if applicable] have been met. I am aware that there are significant penalties for false certification including the possibility of fine and imprisonment."

(B) A description of how the management practices in § 503.14 are met for each site on which bulk sewage sludge is applied.

(C) A description of how the site restrictions in § 503.32(b)(5) are met for each site on which bulk sewage sludge is applied.

(D) When the vector attraction reduction requirement in either § 503.33 (b)(9) or (b)(10) is met, a description of how the vector attraction reduction requirement is met.

(5) If the requirements in § 503.13(a)(2)(i) are met when bulk sewage sludge is applied to agricultural land, forest, a public contact site, or a reclamation site:

(i) The person who prepares the bulk sewage sludge shall develop the following information and shall retain the information for five years.

(A) The concentration of each pollutant listed in Table 1 of § 503.13 in the bulk sewage sludge.

(B) The following certification statement:

"I certify, under penalty of law, that the pathogen requirements in [insert either § 503.32(a) or § 503.32(b)] and the vector attraction reduction requirement in [insert one of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8) if one of those requirements is met] have been met. This determination has been made under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate the information used to determine that the pathogen requirements [and vector attraction reduction requirements] have been met. I am aware that there are significant penalties for false certification including the possibility of fine and imprisonment."

(C) A description of how the pathogen requirements in either § 503.32 (a) or (b) are met.

(D) When one of the vector attraction requirements in § 503.33 (b)(1) through (b)(8) is met, a description of how the vector attraction requirement is met.

(ii) The person who applies the bulk sewage sludge shall develop the following information, retain the information in § 503.17 (a)(5)(ii)(A) through (a)(5)(ii)(G) indefinitely, and retain the information in § 503.17 (a)(5)(ii)(H) through (a)(5)(ii)(M) for five years.

(A) The location, by either street address or latitude and longitude, of each site on which bulk sewage sludge is applied.

(B) The number of hectares in each site on which bulk sewage sludge is applied.

(C) The date and time bulk sewage sludge is applied to each site.

(D) The cumulative amount of each pollutant (i.e., kilograms) listed in Table 2 of § 503.13 in the bulk sewage sludge applied to each site, including the amount in § 503.12(e)(2)(iii).

(E) The amount of sewage sludge (i.e., metric tons) applied to each site.

(F) The following certification statement:

"I certify, under penalty of law, that the requirements to obtain information in § 503.12(e)(2) have been met for each site on which bulk sewage sludge is applied. This determination has been made under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate the information used to determine that the requirements to obtain information have been met. I am aware that there are significant penalties for false certification including fine and imprisonment."

(G) A description of how the requirements to obtain information in § 503.12(e)(2) are met.

(H) The following certification statement:

"I certify, under penalty of law, that the management practices in § 503.14 have been met for each site on which bulk sewage sludge is applied. This determination has been made under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate the information used to determine that the management practices have been met. I am aware that there are significant penalties for false certification including fine and imprisonment."

(I) A description of how the management practices in § 503.14 are met for each site on which bulk sewage sludge is applied.

(J) The following certification statement when the bulk sewage sludge meets the Class B pathogen requirements in § 503.32(b):

"I certify, under penalty of law, that the site restrictions in § 503.32(b)(5) have been met. This determination has been made under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate the information used to determine that the site restrictions have been met. I am aware that there are significant penalties for false certification including fine and imprisonment."

(K) A description of how the site restrictions in § 503.32(b)(5) are met for each site on which Class B bulk sewage sludge is applied.

(L) The following certification statement when the vector attraction reduction requirement in either § 503.33 (b)(9) or (b)(10) is met:

"I certify, under penalty of law, that the vector attraction reduction requirement in [insert either § 503.33(b)(9) or § 503.33(b)(10)] has been met. This determination has been made under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate the information used to determine that the vector attraction reduction requirement has been met. I am aware that there are significant penalties for false certification including the possibility of fine and imprisonment."

(M) If the vector attraction reduction requirements in either § 503.33 (b)(9) or (b)(10) are met, a description of how the requirements are met.

(6) If the requirements in § 503.13(a)(4)(ii) are met when sewage sludge is sold or given away in a bag or

other container for application to the land, the person who prepares the sewage sludge that is sold or given away in a bag or other container shall develop the following information and shall retain the information for five years:

(i) The annual whole sludge application rate for the sewage sludge that does not cause the annual pollutant loading rates in Table 4 of § 503.13 to be exceeded.

(ii) The concentration of each pollutant listed in Table 4 of § 503.13 in the sewage sludge.

(iii) The following certification statement:

"I certify, under penalty of law, that the management practice in § 503.14(e), the Class A pathogen requirement in § 503.32(a), and the vector attraction reduction requirement in [insert one of the vector attraction reduction requirements in § 503.33 (b)(1) through (b)(8)] have been met. This determination has been made under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate the information used to determine that the management practice, pathogen requirements, and vector attraction reduction requirements have been met. I am aware that there are significant penalties for false certification including the possibility of fine and imprisonment."

(iv) A description of how the Class A pathogen requirements in § 503.32(a) are met.

(v) A description of how one of the vector attraction requirements in § 503.33 (b)(1) through (b)(8) is met.

(b) *Domestic septage.* When domestic septage is applied to agricultural land, forest, or a reclamation site, the person who applies the domestic septage shall develop the following information and shall retain the information for five years:

(1) The location, by either street address or latitude and longitude, of each site on which domestic septage is applied.

(2) The number of acres in each site on which domestic septage is applied.

(3) The date and time domestic septage is applied to each site.

(4) The nitrogen requirement for the crop or vegetation grown on each site during a 365 day period.

(5) The rate, in gallons per acre per 365 day period, at which domestic septage is applied to each site.

(6) The following certification statement:

"I certify, under penalty of law, that the pathogen requirements in [insert either § 503.32(c)(1) or § 503.32(c)(2)] and the vector attraction reduction requirements in [insert § 503.33(b)(9), § 503.33(b)(10), or § 503.33(b)(12)] have been met. This determination has been made under my direction and supervision in accordance with the system designed to ensure that qualified personnel properly gather and evaluate the information used to determine that the pathogen requirements and vector attraction reduction requirements have been met. I am aware that there are significant penalties for false certification including the possibility of fine and imprisonment."

(7) A description of how the pathogen requirements in either § 503.33 (c)(1) or (c)(2) are met.

(8) A description of how the vector attraction reduction requirements in § 503.33 (b)(9), (b)(10), or (b)(12) are met.

(Approved by the Office of Management and Budget under control number 2040-0157)

§ 503.18 Reporting.

(a) Class I sludge management facilities, POTWs (as defined in 40 CFR 501.2) with a design flow rate equal to or greater than one million gallons per day, and POTWs that serve 10,000 people or more shall submit the following information to the permitting authority:

(1) The information in § 503.17(a), except the information in § 503.17 (a)(3)(ii), (a)(4)(ii) and in (a)(5)(ii), for the appropriate requirements on February 19 of each year.

(2) The information in § 503.17 (a)(5)(ii)(A) through (a)(5)(ii)(G) on [insert the month and day from the date of publication of this rule] of each year when 90 percent or more of any of the cumulative pollutant loading rates in Table 2 of § 503.13 is reached at a site.

(Approved by the Office of Management and Budget under control number 2040-0157)

Subpart C—Surface Disposal

§ 503.20 Applicability.

(a) This subpart applies to any person who prepares sewage sludge that is placed on a surface disposal site, to the owner/operator of a surface disposal site, to sewage sludge placed on a surface disposal site, and to a surface disposal site.

(b) This subpart does not apply to sewage sludge stored on the land or to the land on which sewage sludge is stored. It also does not apply to sewage sludge that remains on the land for longer than two years when the person who prepares the sewage sludge demonstrates that the land on which the sewage sludge remains is not an active sewage sludge unit. The demonstration shall include the following information, which shall be retained by the person who prepares the sewage sludge for the period that the sewage sludge remains on the land:

(1) The name and address of the person who prepares the sewage sludge.

(2) The name and address of the person who either owns the land or leases the land.

(3) The location, by either street address or latitude and longitude, of the land.

(4) An explanation of why sewage sludge needs to remain on the land for longer than two years prior to final use or disposal.

(5) The approximate time period when the sewage sludge will be used or disposed.

(c) This subpart does not apply to sewage sludge treated on the land or to the land on which sewage sludge is treated.

§ 503.21 Special definitions.

(a) *Active sewage sludge unit* is a sewage sludge unit that has not closed.

(b) *Aquifer* is a geologic formation, group of geologic formations, or a portion of a geologic formation capable of yielding ground water to wells or springs.

(c) *Contaminate an aquifer* means to introduce a substance that causes the maximum contaminant level for nitrate in 40 CFR 141.11 to be exceeded in ground water or that causes the existing concentration of nitrate in ground water to increase when the existing concentration of nitrate in the ground water exceeds the maximum contaminant level for nitrate in 40 CFR 141.11.

(d) *Cover* is soil or other material used to cover sewage sludge placed on an active sewage sludge unit.

(e) *Displacement* is the relative movement of any two sides of a fault measured in any direction.

(f) *Fault* is a fracture or zone of fractures in any materials along which strata on one side are displaced with respect to strata on the other side.

(g) *Final cover* is the last layer of soil or other material placed on a sewage sludge unit at closure.

(h) *Holocene time* is the most recent epoch of the Quaternary period, extending from the end of the Pleistocene epoch to the present.

(i) *Leachate collection system* is a system or device installed immediately above a liner that is designed, constructed, maintained, and operated to collect and remove leachate from a sewage sludge unit.

(j) *Liner* is soil or synthetic material that has a hydraulic conductivity of 1×10^{-7} centimeters per second or less.

(k) *Lower explosive limit for methane gas* is the lowest percentage of methane gas in air, by volume, that propagates a flame at 25 degrees Celsius and atmospheric pressure.

(l) *Qualified ground-water scientist* is an individual with a baccalaureate or